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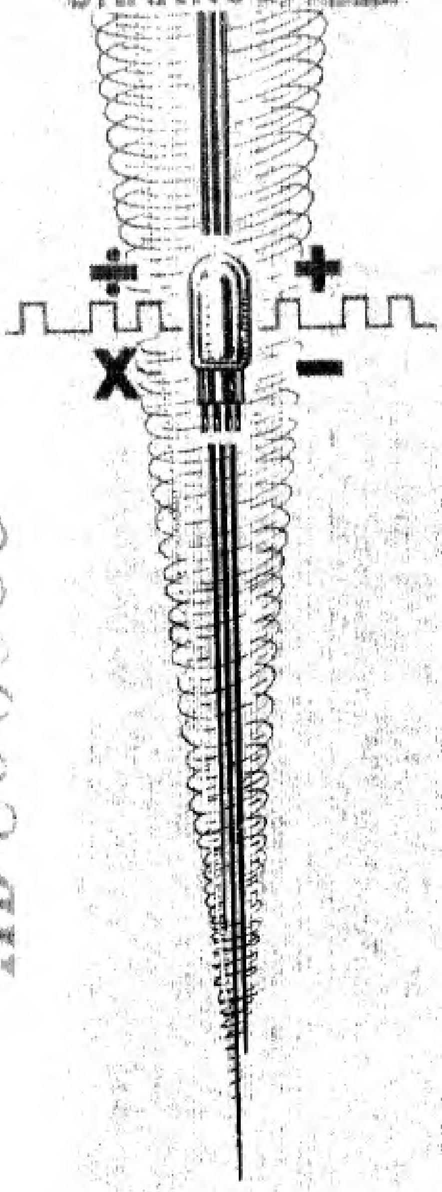

PROJECT WHIRLWIND

Contract N5ori60

SUMMARY REPORT NO. 2

VOLUME 15

CRYSTALS, FLIP-FLOP CIRCUITS, A.C. COUPLING

SERVOMECHANISMS LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SPECIAL DEVICES CENTER

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH

(1)

(9) ~~PROJECT WHIRLWIND~~
Summary Report No. 2.
(11) November, 1947

(12) 162p.

(6) Project Whirlwind.
Volume 15.

CRYSTALS, FLIP-FLOP CIRCUITS AND AC COUPLING.

Volume 15 of 22 Volumes

(15) N5ori-60

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

220 072

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INTRODUCTION

A high back-voltage germanium-crystal rectifier possesses many advantages over the vacuum-tube diode. It has a much lower forward resistance and has a current-voltage characteristic which passes through the origin. In addition it is small, requiring little space, no heater power, and having very small interelectrode capacitance. Its disadvantage is that it has a back conductance which frequently cannot be neglected and which increases with temperatures. Crystals are used in Whirlwind I for clamping (d-c restoration), for isolation in coupling trigger sources to flip-flops, for mixing signals in a common load, in high-speed multi-position switches, and in pulse-generating circuits. In addition, Sylvania is developing special high-conductivity crystals for coupling to the digit-transfer bus and for use in the deflection circuits. Measurements have been made to determine the characteristics of crystals, particularly at overload and at high ambient temperatures. These measurements are reported in R-106, R-111, R-108, and M-68. Close contact has been maintained with the crystal group at Sylvania, where life tests, including life tests under pulse conditions at high ambient temperatures, are being conducted. See M-58 and E-41. Our experience with crystal failures and deterioration is described in M-110. A tester for selection of crystals for computer circuits is described in E-37 and M-92, and is shown in photograph FB-273. A clamp to avoid overheating when soldering is shown in photograph FB-303. Standard symbols for crystals are set forth in E-69.

An element which has two stable states, symbol FF, is essential to the Whirlwind computers as may be seen from the block diagrams. By using a resistance-coupled multivibrator or flip-flop, employing two pentodes, such an element is obtained having a switching time of approximately 0.1 microsecond. The development of a reliable, high-speed flip-flop has been a prime consideration of the electronics group and a continuous investigation of flip-flop circuits, including stability, tube characteristics, component tolerances, and life has been underway since the spring of 1946 and will continue. This investigation is described in R-113, E-42, E-56, E-57, M-99, M-64 and M-138.

In order to avoid the cascading of power supplies, the amplification of power-supply voltage drift, filament-transformer

isolation, and other difficulties accompanying direct coupling, a scheme of a-c coupling has been devised which preserves the functional advantages of d-c coupling. This scheme requires that each flip-flop in the computer be triggered twice by two pulses one microsecond apart (so that it returns to its original state) during a time in the cycle when the flip-flop is not otherwise active. This is done frequently enough so that the coupling capacitors do not have time to discharge; the desired d-c level is obtained by use of clamping diodes. This is an important factor in the Whirlwind computers which makes operation more reliable by permitting wider tolerances on power-supply voltages and pulse amplitudes. It is described in M-77, E-39, M-91, and E-47.

REFERENCE INDEX

M Series Memorandums

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M-58	15	M-100	8	M-136	7
M-61	8	M-101	11	M-137	7
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E-24	7	E-53	13
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E-37	15	E-57	15
E-38	19	E-58	19
E-39	15	E-59	19
E-41	15	E-60	19
E-42	15	E-61	16
E-44	19	E-63	19
E-45	19	E-64	15
E-47	15	E-68	13
E-48	19	E-69	15
E-49	19	E-71	19
E-50	16	E-73	16

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R-49	14
R-63	14
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R-89	19
R-90	4
R-94	14
R-98	14
R-100	14
R-102	14
R-104	16
R-106	15
R-108	15
R-109	19
R-110	9
R-111	15
R-113	15
R-114	8
R-115	4
R-116	4
R-117	16
R-118	16
R-120	10
R-121	19
R-122	18
R-123	17
R-124	11
R-125	14
R-126	19
R-127	5
R-127	6
R-128	10
R-129	12
R-130	9
R-131	10
R-132	10

and the lower curfe on the negative side. The middle curve is an average of the twelve crystals measured.

Written by: Ray R. Ellis

Engineer: David R. Brown

Approved: Jay W. Forrester

RLE:has

TEST CIRCUITS FOR 1N34 CRYSTAL DIODE CHARACTERISTICS

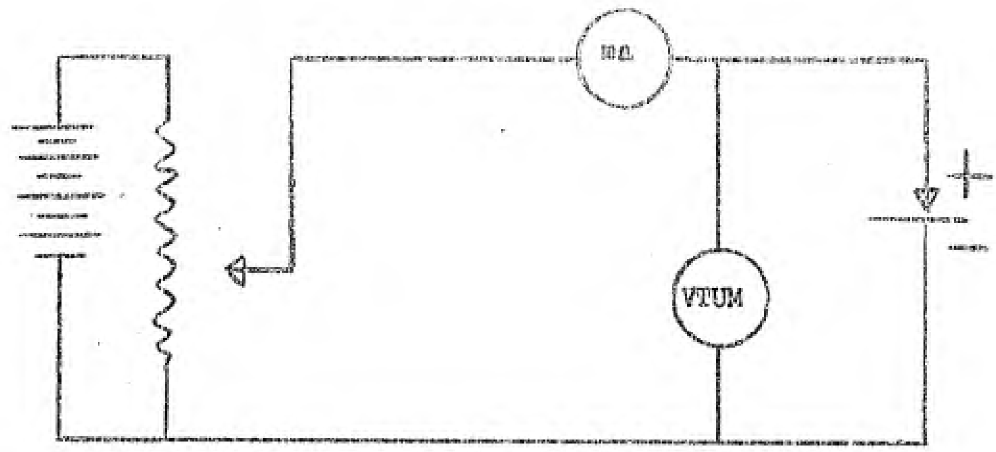


FIGURE 1 - CIRCUIT DIAGRAM

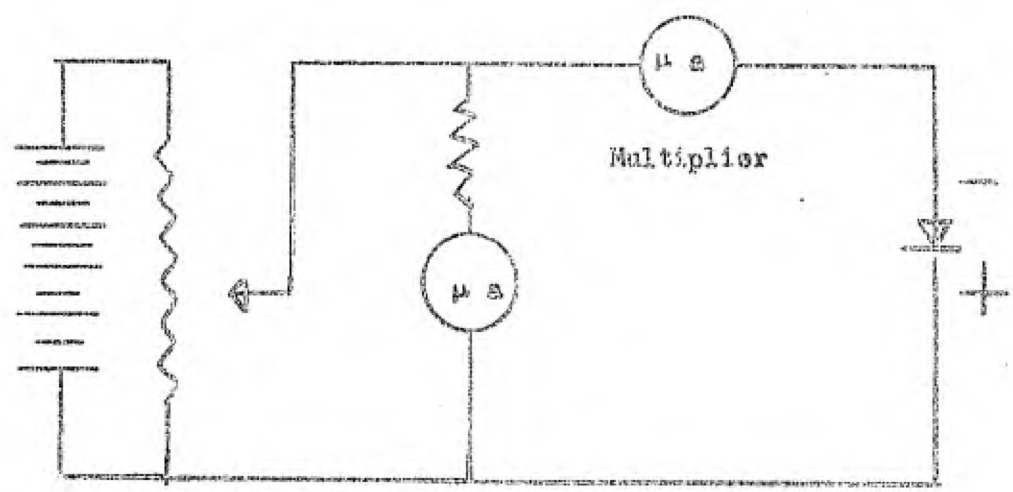
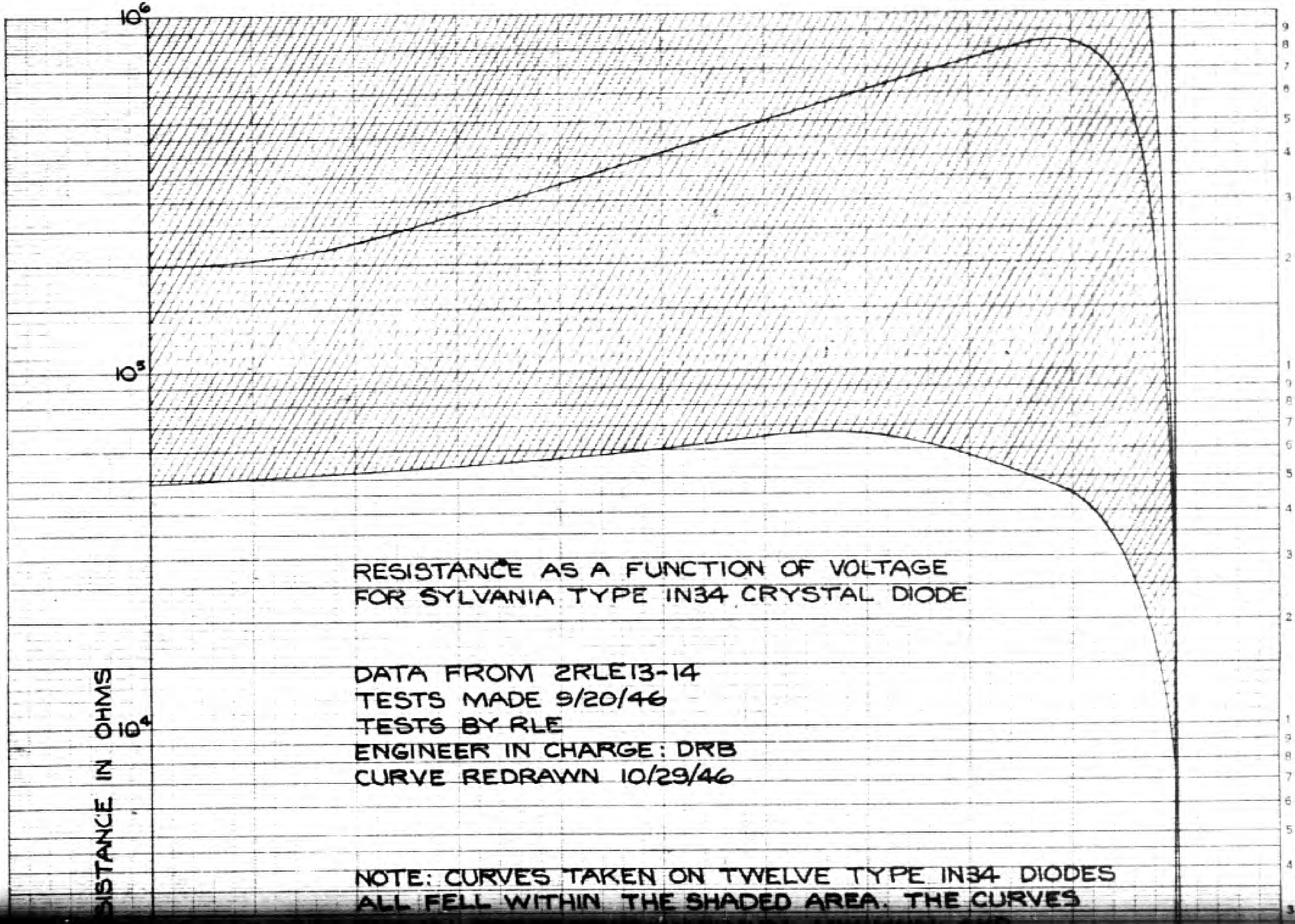
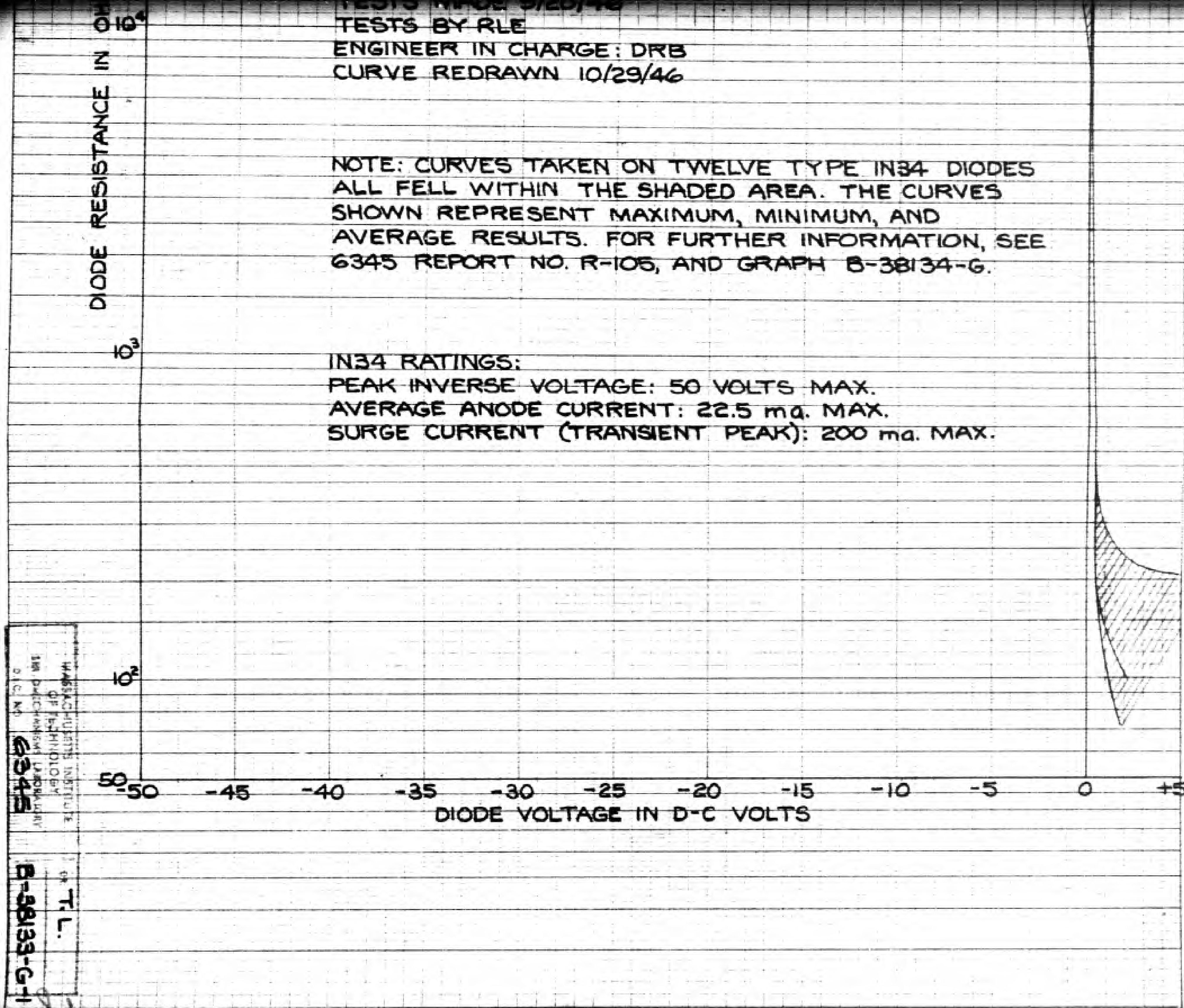


FIGURE 2 - REFINED CIRCUIT FOR LOW-VOLTAGE READINGS


10^6
10^5
10^4
RESISTANCE IN OHMS
RESISTANCE AS A FUNCTION OF VOLTAGE
FOR SYLVANIA TYPE IN34 CRYSTAL DIODE
DATA FROM 2RLE13-14
TESTS MADE 9/20/46
TESTS BY RLE
ENGINEER IN CHARGE: DRB
CURVE REDRAWN 10/29/46
NOTE: CURVES TAKEN ON TWELVE TYPE IN34 DIODES
ALL FELL WITHIN THE SHADED AREA. THE CURVES


TESTS BY RLE
ENGINEER IN CHARGE: DRB
CURVE REDRAWN 10/29/46
NOTE: CURVES TAKEN ON TWELVE TYPE IN34 DIODES ALL FELL WITHIN THE SHADED AREA. THE CURVES SHOWN REPRESENT MAXIMUM, MINIMUM, AND AVERAGE RESULTS. FOR FURTHER INFORMATION, SEE 6345 REPORT NO. R-105, AND GRAPH B-38134-G.
IN34 RATINGS:
PEAK INVERSE VOLTAGE: 50 VOLTS MAX.
AVERAGE ANODE CURRENT: 22.5 ma. MAX.
SURGE CURRENT (TRANSIENT PEAK): 200 ma. MAX.
DIODE RESISTANCE IN OH
10^4
10^3
10^2
50
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
+5
DIODE VOLTAGE IN D-C VOLTS
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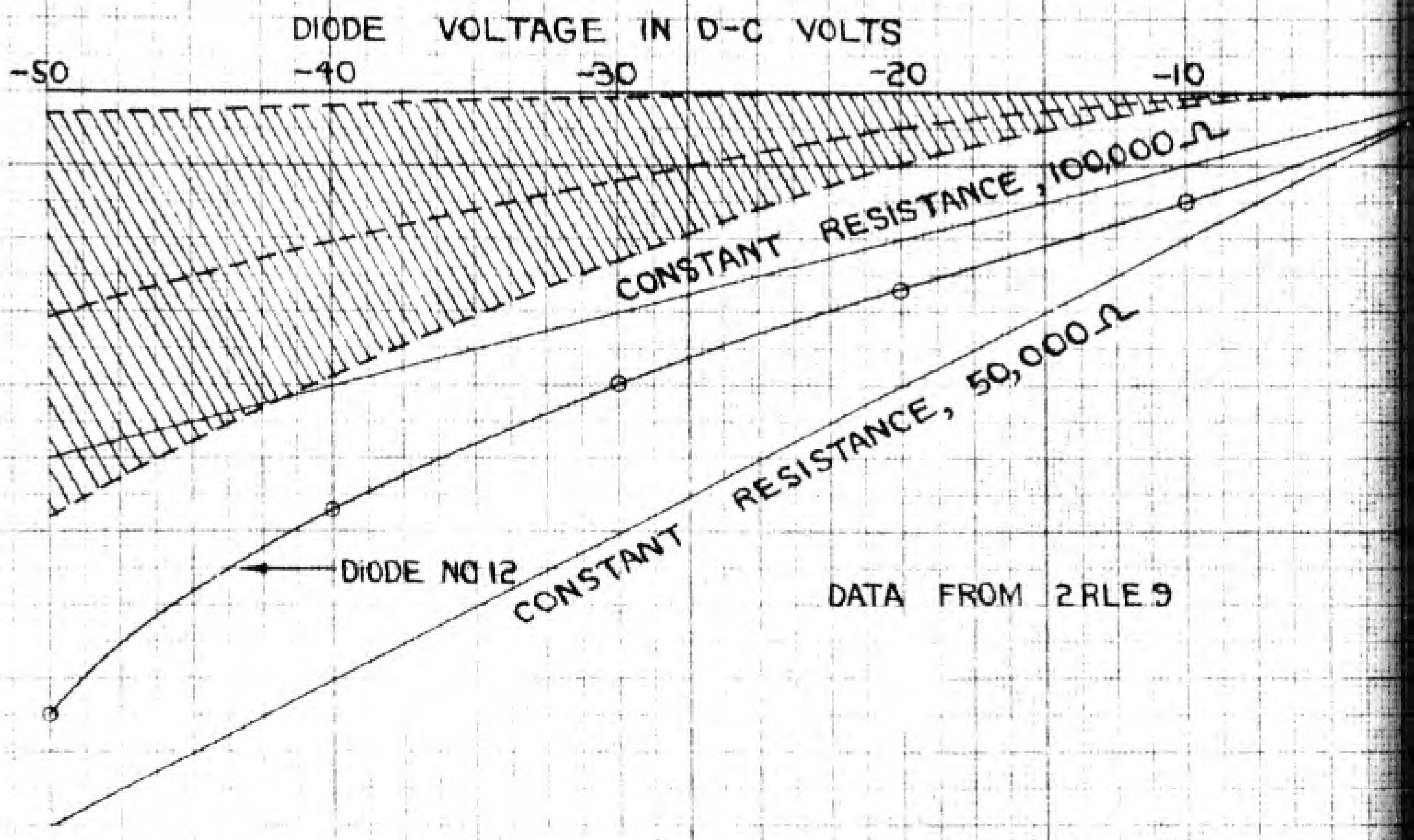
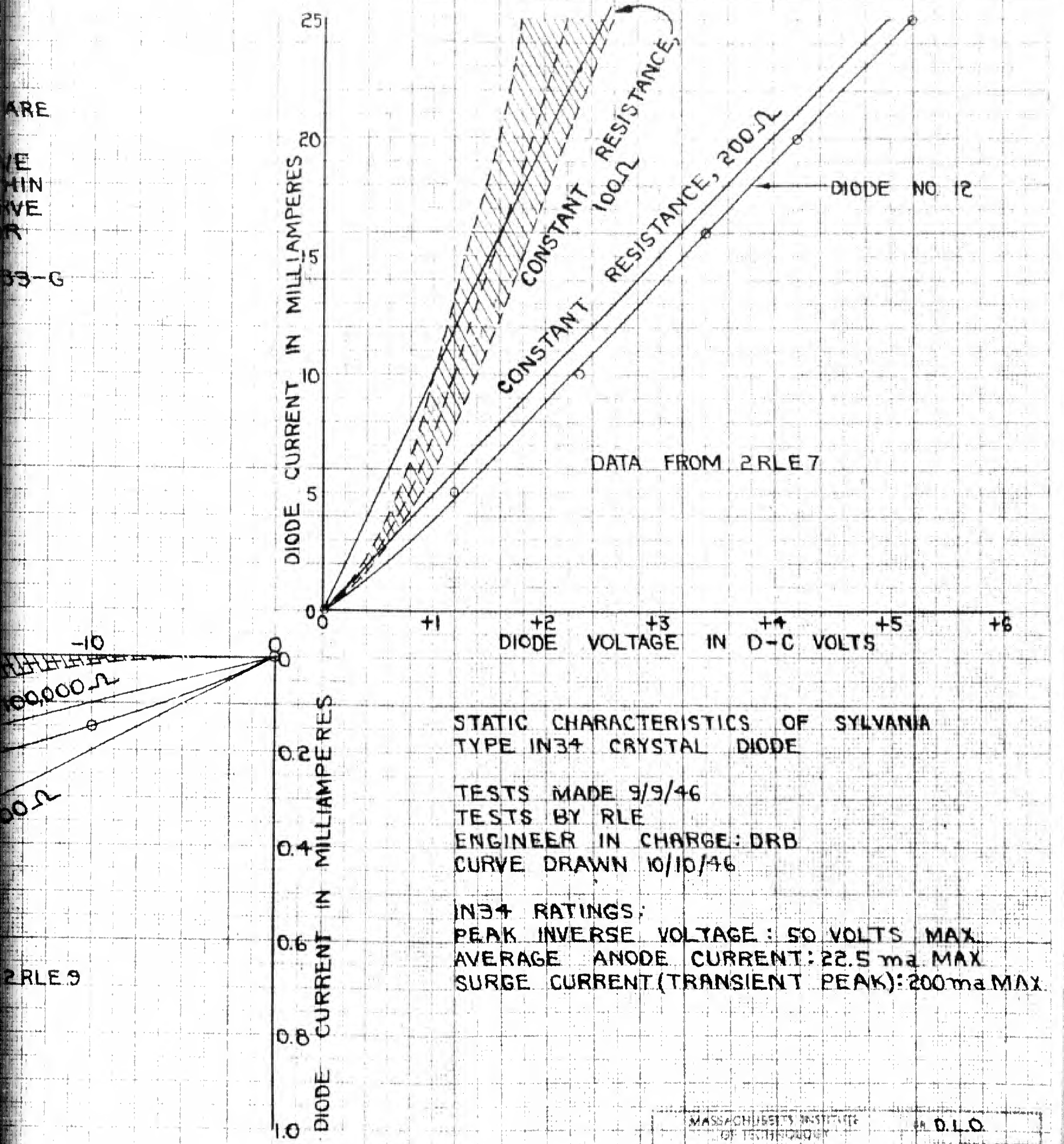
D.I.C. NO. 6345
T.L.
B-38133-G-1

NOTES:

(1) CURRENT SCALES FOR THE TWO GRAPHS ARE DIFFERENT.

(2) CURVES FOR NOS. 1 TO 11 OF THE TWELVE TYPE IN34 DIODES TESTED FELL WITHIN THE SHADED AREAS, WHILE THE CURVE FOR NO.12 IS SHOWN SEPARATELY. FOR FURTHER INFORMATION, SEE 6345 REPORT NO. R-105, AND GRAPH B-38133-G





STATIC CHARACTERISTICS OF SYLVANIA
TYPE IN34 CRYSTAL DIODE

TESTS MADE 9/9/46
TESTS BY RLE
ENGINEER IN CHARGE: DRB
CURVE DRAWN 10/10/46

IN34 RATINGS:
PEAK INVERSE VOLTAGE: 50 VOLTS MAX.
AVERAGE ANODE CURRENT: 22.5 ma MAX.
SURGE CURRENT (TRANSIENT PEAK): 200 ma MAX.

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B-38134-G-1

6345
Report No. R-111

Servomechanisms Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts

Date of Report:	January 22, 1947	
Written by:	Ray L. Ellis	Drawings: A-38161-G
Subject:	Overload and Temperature Test on Sylvania 1N34 Germanium-Crystal Diodes.	A-38162-G A-38163-G A-38164-G
References:	A. R-106, "Characteristics of Sylvania 1N34 Germanium-Crystal Diodes, Ray L. Ellis, December 3, 1946.	A-38166-G A-38167-G A-38168-G A-38169-G
	B. M-68, "Sylvania 1N34 Germanium-Crystal Diode Back Conduction Characterisitcs, R. B. Palmiter, April 28, 1947	A-38172-G A-38173-G A-30467 A-30476

Object:

To determine what effect overloading these diodes, both in the forward and back direction has upon the characteristics of the diodes.

To determine the effect of increased ambient temperature on the characteristics of the diodes.

Summary

Overloading a diode to twice its maximum rated forward current produces no permanent effect. Overloading it five times its maximum rated forward current changes its forward characteristic; forward resistance increases about 12 per cent. Further overloading not only increases these changes but also produces a permanent change in back resistance. Tests show some diodes will take one ampere forward current before total breakdown. Test on ten diodes at 23.5°C indicate that an increase of back voltage beyond 50 volts is undesirable. Overloading diodes to twice their maximum rated back voltage is impossible without destroying the diode or permanently changing the diode characteristic.

Temperature tests show that over the range of 80°C above room temperature, change in diode forward characteristics is small.

Temperature changes of 20°C, however, do change the back characteristics. An increase of 20°C above room temperature will cause the back resistance at low back voltages to drop as much as 80% of the resistance at room temperature. The resistance will return to its

original value as the temperature is returned to room temperature. Greater increases in temperature further decreases back resistance. The tests indicate that as temperature increases the safe maximum back voltage decreases.

Overload Tests in the Forward Direction

First, the characteristics over the rated range were measured on four diodes. The test circuit was the same as that previously used to determine the characteristics of 1N34 diodes and is shown in Drawing No. A-30467. Graphs A-38172-G and A-38173-G, show the characteristics over the range to both forward and back rated conditions for one of the diodes tested.

Overloads were put on the four diodes by applying multiples of maximum rated current. The first overload was twice the maximum rated current, 50 ma. With this current, the voltage across one diode measured 2.7 volts, a resistance of 54 ohms. No change was indicated after five minutes. This overload produced no change in the forward characteristic of the diode. When the diode was subjected to an overload of five times the maximum rated current, 125 ma. the voltage was 5.2 volts. The voltage drifted to 5.0 volts in 30 seconds and at the end of five minutes reached 4.5 volts. This overloading produced a permanent change in the diode. When the diode was given the original test again at rated conditions, the forward resistance was approximately 12 per cent greater for all values of current. An overload of ten times the maximum rated current, 250 ma. produced a voltage of 5.3 volts. A slow drifting of the current was observed and after two and one-half minutes the current jumped to 265 ma. and the voltage at the same time dropped to 5.0 volts. After five minutes, the current and voltage stabilized at 264 ma. and 5.2 volts, a resistance of 20 ohms. Results of repeating the original test over the range of rated conditions showed the forward resistance of the diode was permanently increased 25 per cent by overloading ten times the maximum rated current. Next, the current was slowly increased. With 800 ma. and 6.5 volts, no apparent damage was produced. At slightly more than one ampere, the diode burned out with a snap and a flash of blue light. The wax filler was forced out the side. The three other diodes tested exhibited approximately the same behavior.

Testing three more diodes over the range of rated back voltage after each forward overloading showed that forward overloading to five times the rated forward current caused no effect on the original back characteristics. However, greater forward overloading changed the back characteristics. When the back resistance was measured at 50 volts after an overload of ten times rated forward current, the back

resistance of the three diodes was found to have changed +77 per cent, -50 per cent, and -74 per cent of the original back resistance at 50 volts. After a forward overload of ten times rated forward current, the back resistance changed as much as 77 per cent while the forward resistance increased but 25 per cent.

Overload Tests in the Back Direction

The circuit used for the back overload tests was similar to that used for the forward overload test. The ambient temperature was 23.5°C. Characteristics over the range to maximum rated back voltage were measured. For one diode, the resistance at maximum rated back voltage, 50 volts, was 167,000 ohms. The back voltage was gradually increased. The current reached 5.0 ma. at 70 volts. Thereafter, the current increased rapidly. At 71 volts, the current was 8.5 ma. Just beyond 71 volts the current suddenly jumped to 24 ma. and the voltage at the same time dropped to 34 volts. Any further attempt to increase the applied voltage, resulted in increased current and a decreased voltage across the diode, indicating a negative slope of the characteristic. With 30 ma. current through the diode, the voltage across had dropped to 30 volts. Here it was unstable; the voltage drifted to 26 volts in three minutes. This overload definitely changed the characteristics of the diode. Reducing the voltage to zero volts and gradually increasing it again showed that the negative slope appeared at a lower voltage, 54 volts. At 38 volts and 80 ma. the diode burned out and opened circuit.

Tests were made on ten more diodes. The results showed that for the 11 diodes tested, the range of critical voltage was between 66 and 160 volts. The rated maximum voltage of 50 volts for the back direction should not be exceeded.

Figure A-30476, taken from Reference B, illustrates the negative slope observed in these tests.

Effect of Increased Ambient Temperature

The four graphs, A-38166-G, A-38167-G, A-38168-G, and A-38169-G, show the relation of resistance to forward current for four diodes at five ambient temperatures: 23.5°C, 40°C, 60°C, and 100°C. They show that resistance decreases as temperature increases. The decrease, however, is small, about 12 per cent for a 20°C increase.

Graphs A-38161-G, A-38162-G, A-38163-G, and A-38164-G, show resistance vs. back voltage for the same four diodes at the five temperatures. The back resistance decreases rapidly with increase in

temperature. At 50 volts, when the temperature increased to 100°C, resistance decreased as much as 91 per cent of that at 23.5°C. And, at 30 volts when the temperature increased from 23.5°C to 40°C, resistance decreased as much as 84 per cent.

Precautions in Wiring

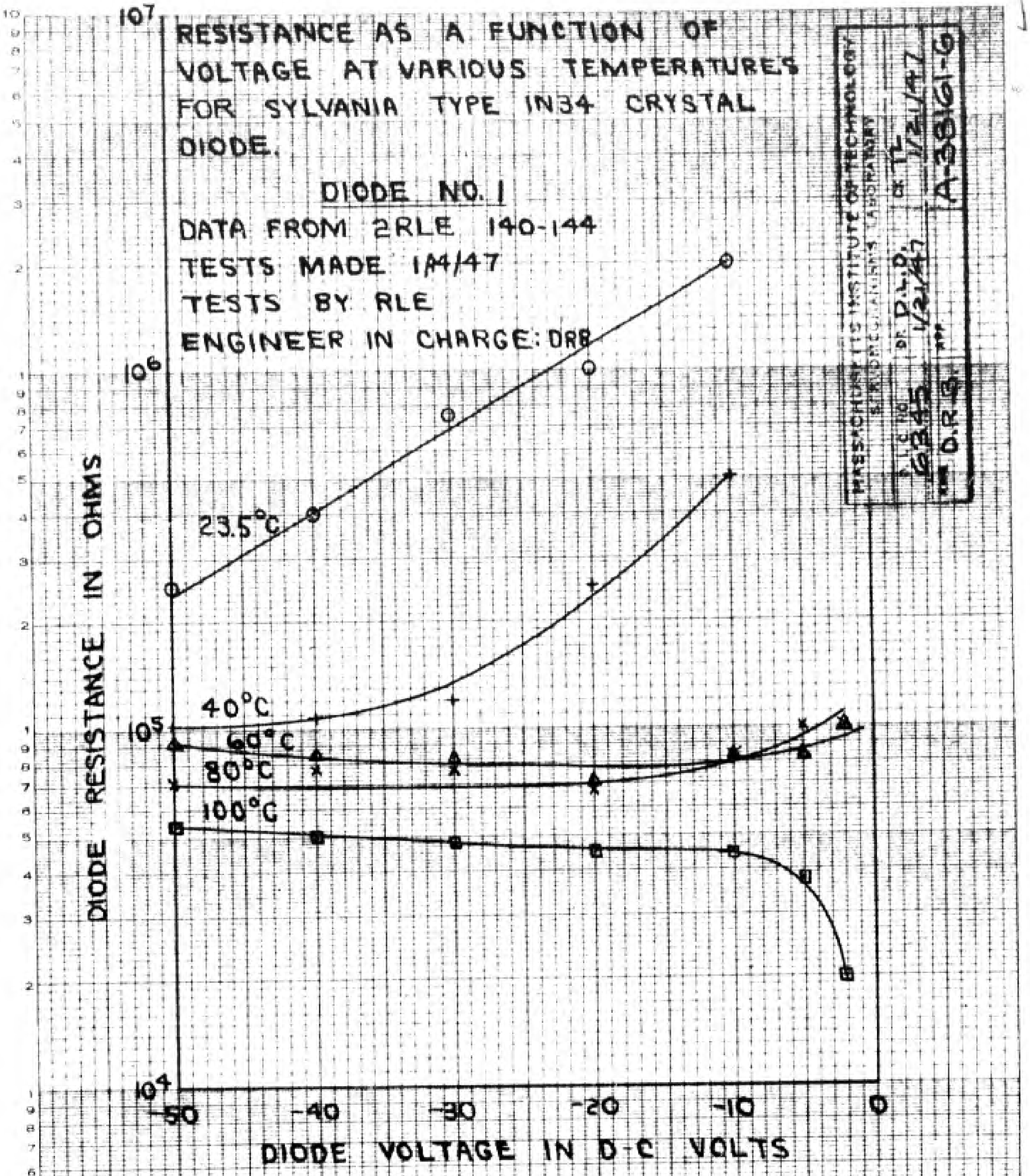
Care must be exercised in soldering these diodes as excessive heat can permanently change the characteristics. The lead between the crystal and the terminal to which the lead is to be soldered should be grasped with a pair of flat-nosed pliers or a clip especially designed for the purpose. A minimum lead length of 3/8 inch is recommended. A maximum lead length of 3/4 inch is recommended to provide adequate support for the diode. A simple tester for testing large numbers of 1N34's will soon be available. The tester will measure the resistance of the diode at several applied voltages.

Technician: Ray L. Ellis

Engineer: David R. Brown

Approved: JF

RLE:has



FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38162-G, A-38163-G, AND A-38164-G. FOR FURTHER INFORMATION, SEE 6345 REPORT R-111.

USED IN 6345 REPORT R-111

NO. 340-L310 DIETZGEN GRAPH PAPER SEMI-LOGARITHMIC 4 CYCLES X 10 DIVISIONS PER INCH

EUGENE DIETZGEN CO. MADE IN U.S.A.

RESISTANCE AS A FUNCTION OF VOLTAGE AT VARIOUS TEMPERATURES FOR SYLVANIA TYPE IN34 CRYSTAL DIODE.

DIODE NO. 2

DATA FROM 2RLE 140-144
TESTS MADE 1/14/47
TESTS BY RLE
ENGINEER IN CHARGE: DRB

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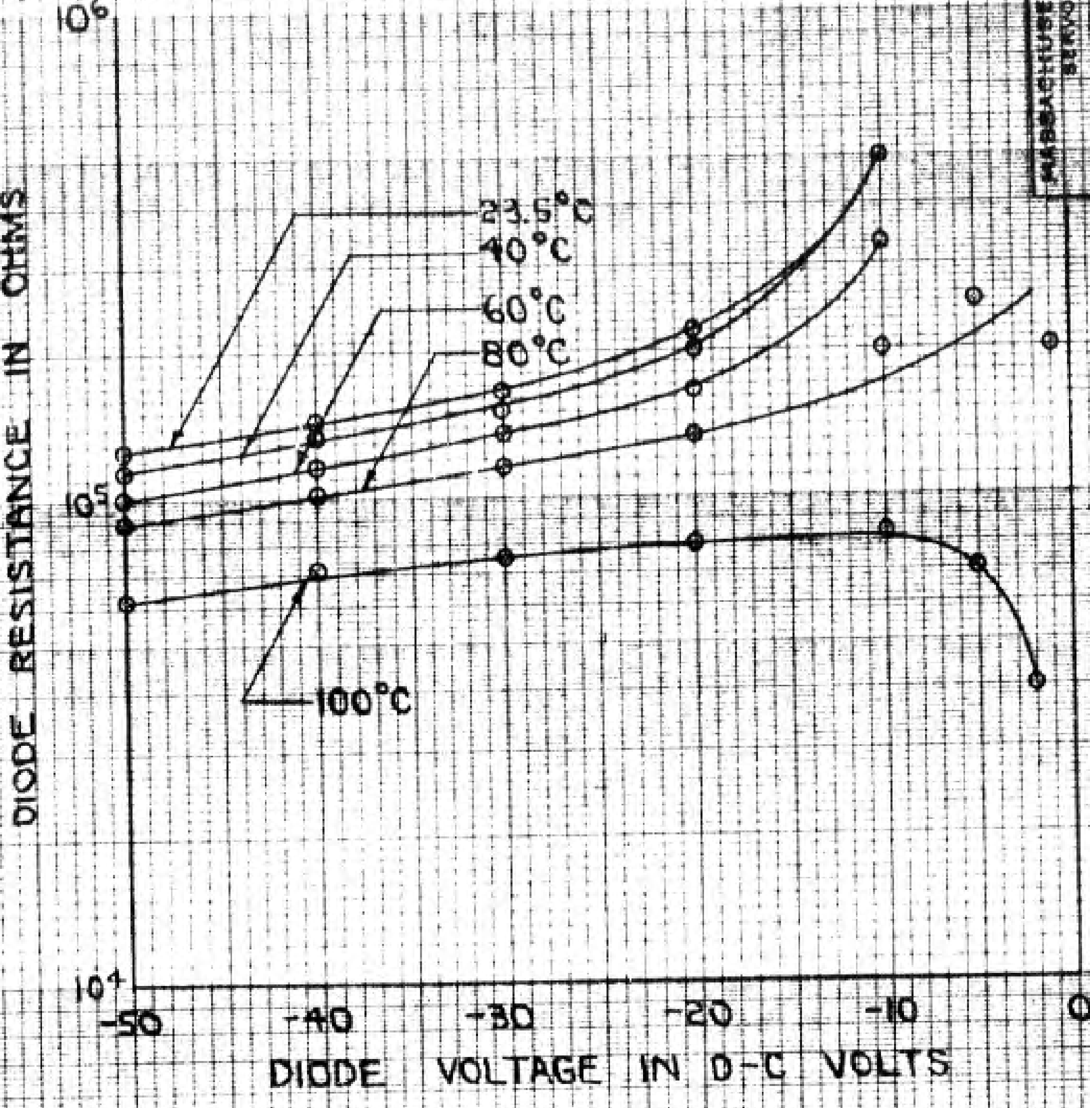
CK. T.L. 1/21/47
APP. D.R.B.
A-38162-G



FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38161-G, A-38163-G, AND A-38164-G. FOR FURTHER INFORMATION, SEE 6345 REPORT R-111

USED IN 6345 REPORT R-111

RESISTANCE AS A FUNCTION OF VOLTAGE
AT VARIOUS TEMPERATURES FOR
SYLVANIA TYPE IN34 CRYSTAL DIODE.
DIODE NO. 3
DATA FROM 2RLE 140-144
TESTS MADE 1/14/47
TESTS BY RLE
ENGINEER IN CHARGE: DRB

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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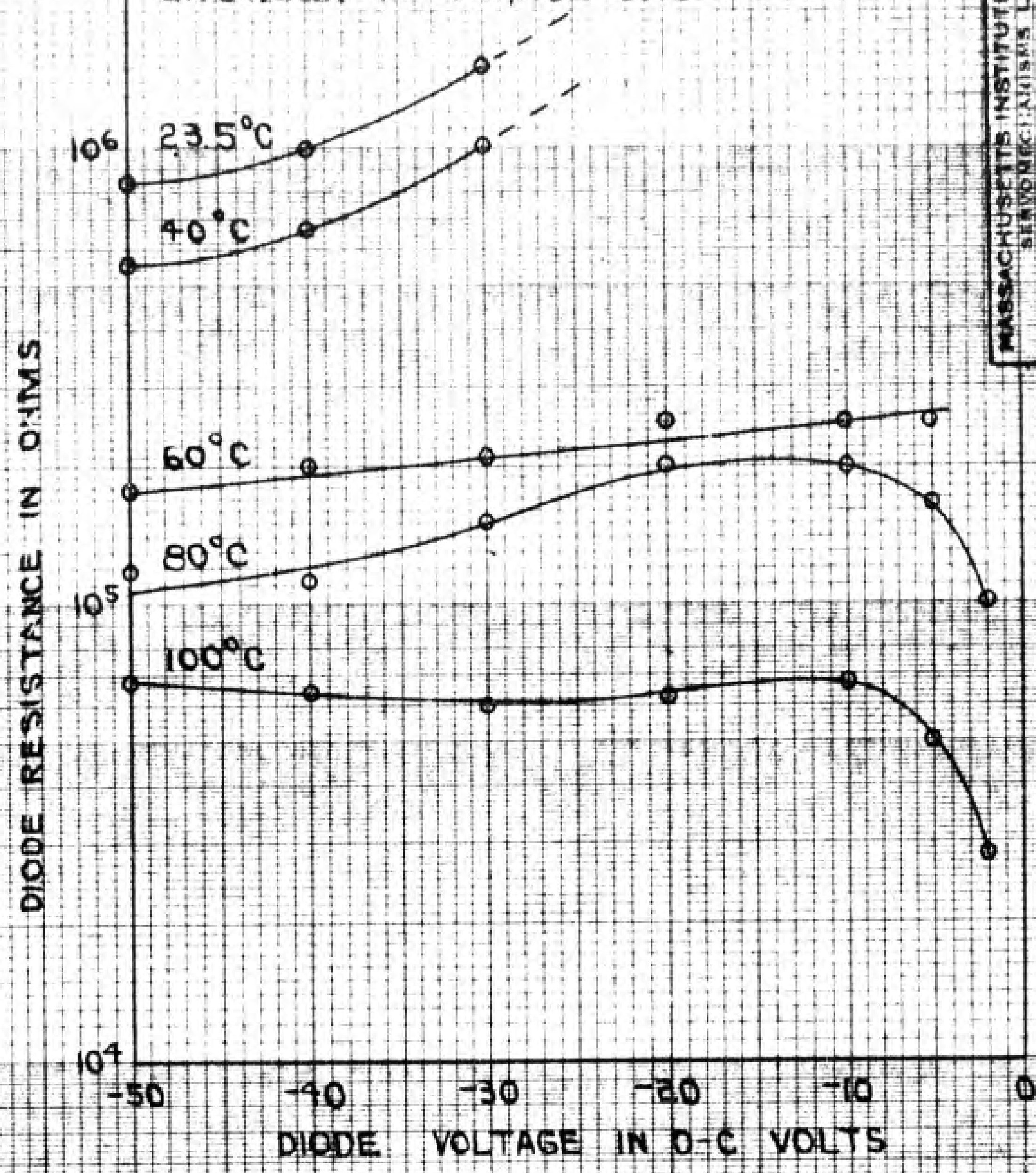
APP. D.R.B. | A-38163-G



FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38161-G, A-38162-G, AND A-38164-G. FOR FURTHER INFORMATION, SEE 6345 REPORT NO. R-111.

USED IN 6345 REPORT R-111

RESISTANCE AS A FUNCTION OF VOLTAGE AT VARIOUS TEMPERATURES FOR SYLVANIA TYPE IN34 CRYSTAL DIODE.

DIODE NO. 4

DATA FROM 2RLE 129-132

TESTS MADE 1/6/47

TESTS BY RLE

ENGINEER IN CHARGE: DRB

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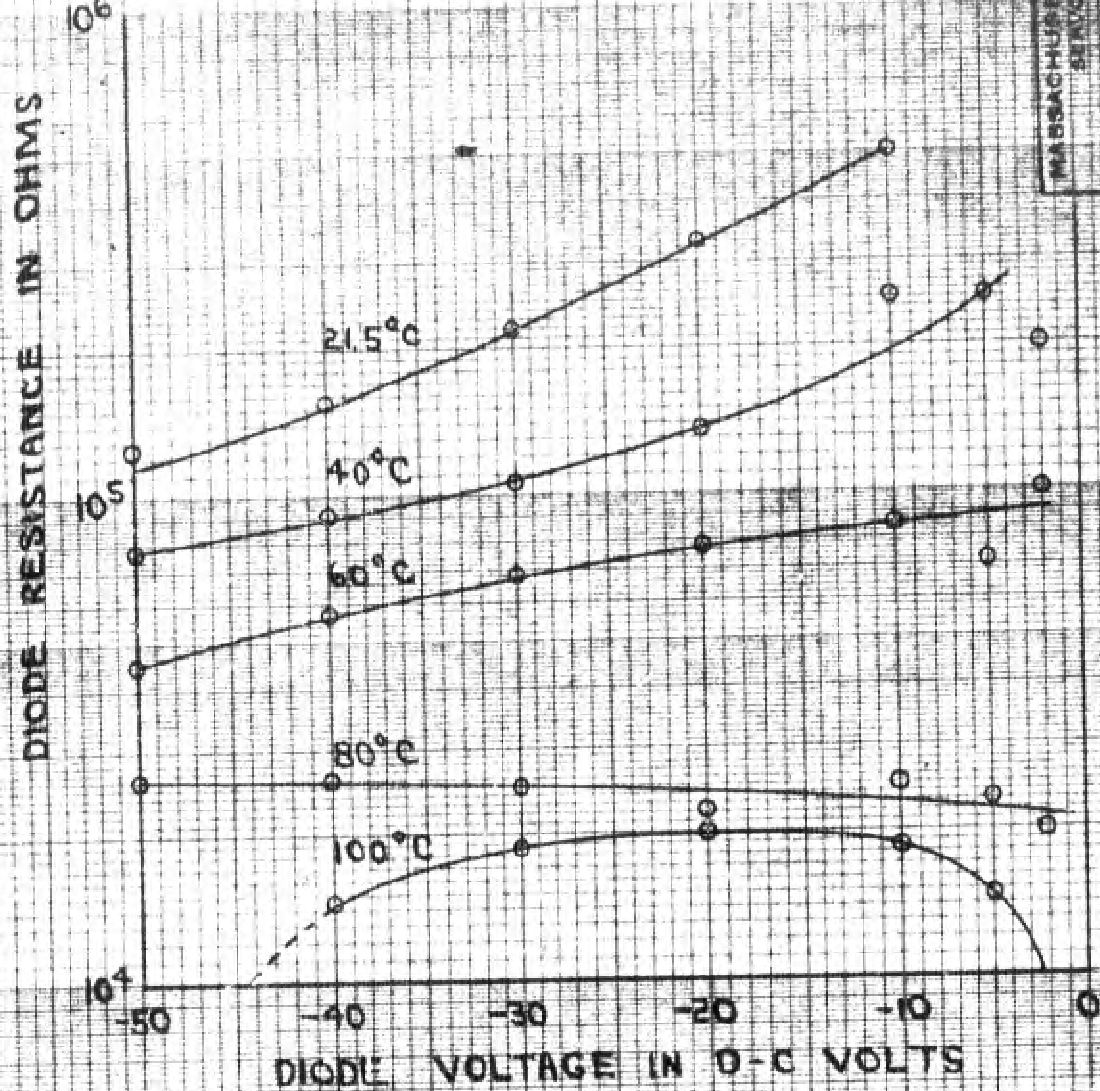
D.I.C. NO. 6345 DR. D.L.O. 1/21/47 CK. JE 1/21/47 APP. D.R.B.
A-38164-G



FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38161-G, A-38162-G, AND A-38163-G. FOR FURTHER INFORMATION, SEE 6345 REPORT R-111.

USED IN 6345 REPORT R-111

RESISTANCE AS A FUNCTION OF VOLTAGE AT VARIOUS TEMPERATURES FOR SYLVANIA TYPE IN34 CRYSTAL DIODE.

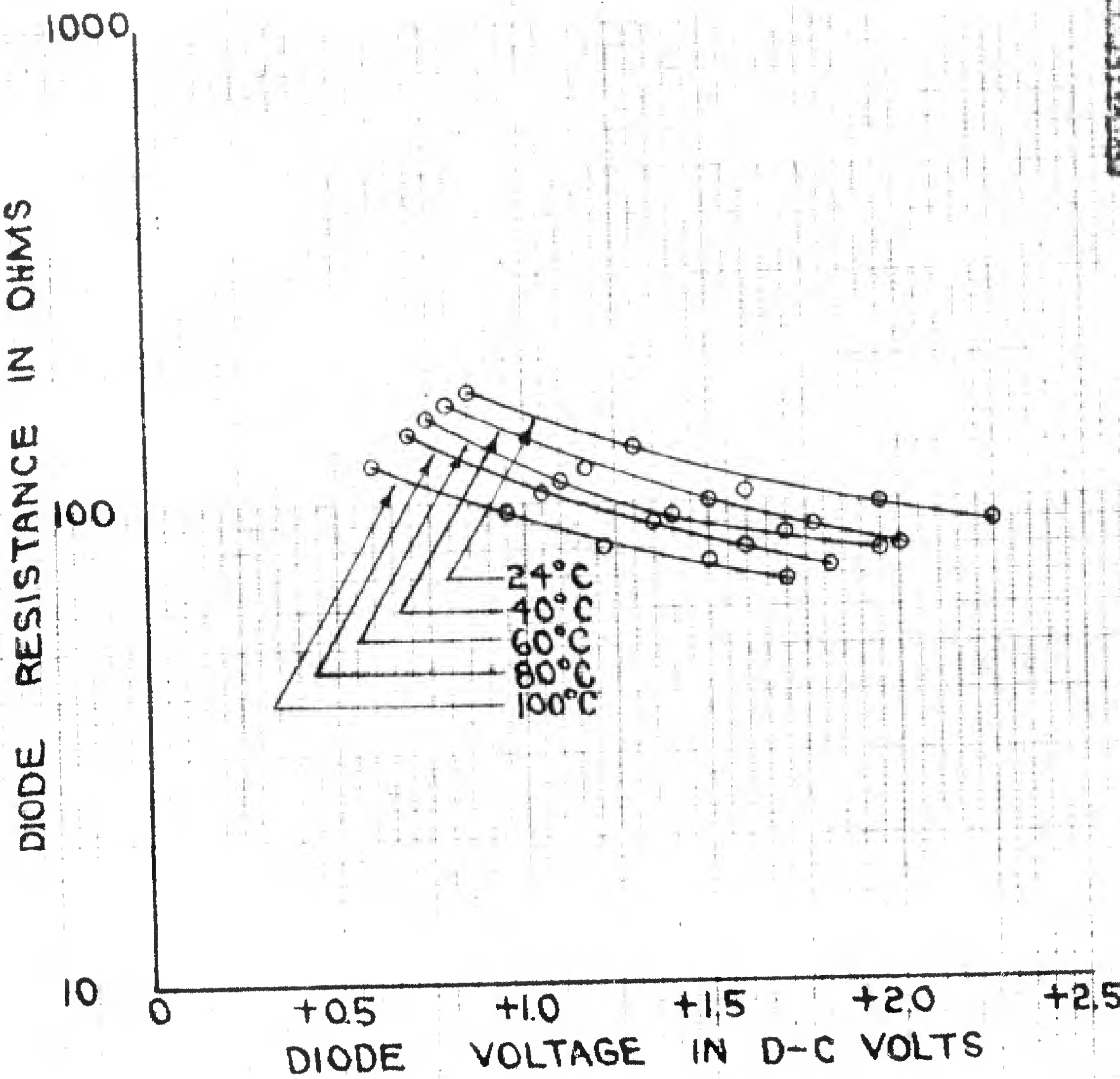
DIODE NO. 1

DATA FROM 2RLE 140-144

TESTS MADE 1/14/47

TESTS BY RLE

ENGINEER IN CHARGE: DRB



FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38167-G, A-38168-G, AND A-38169-G. FOR FURTHER INFORMATION, SEE 6345 REPORT R-111.

USED IN 6345 REPORT R-111

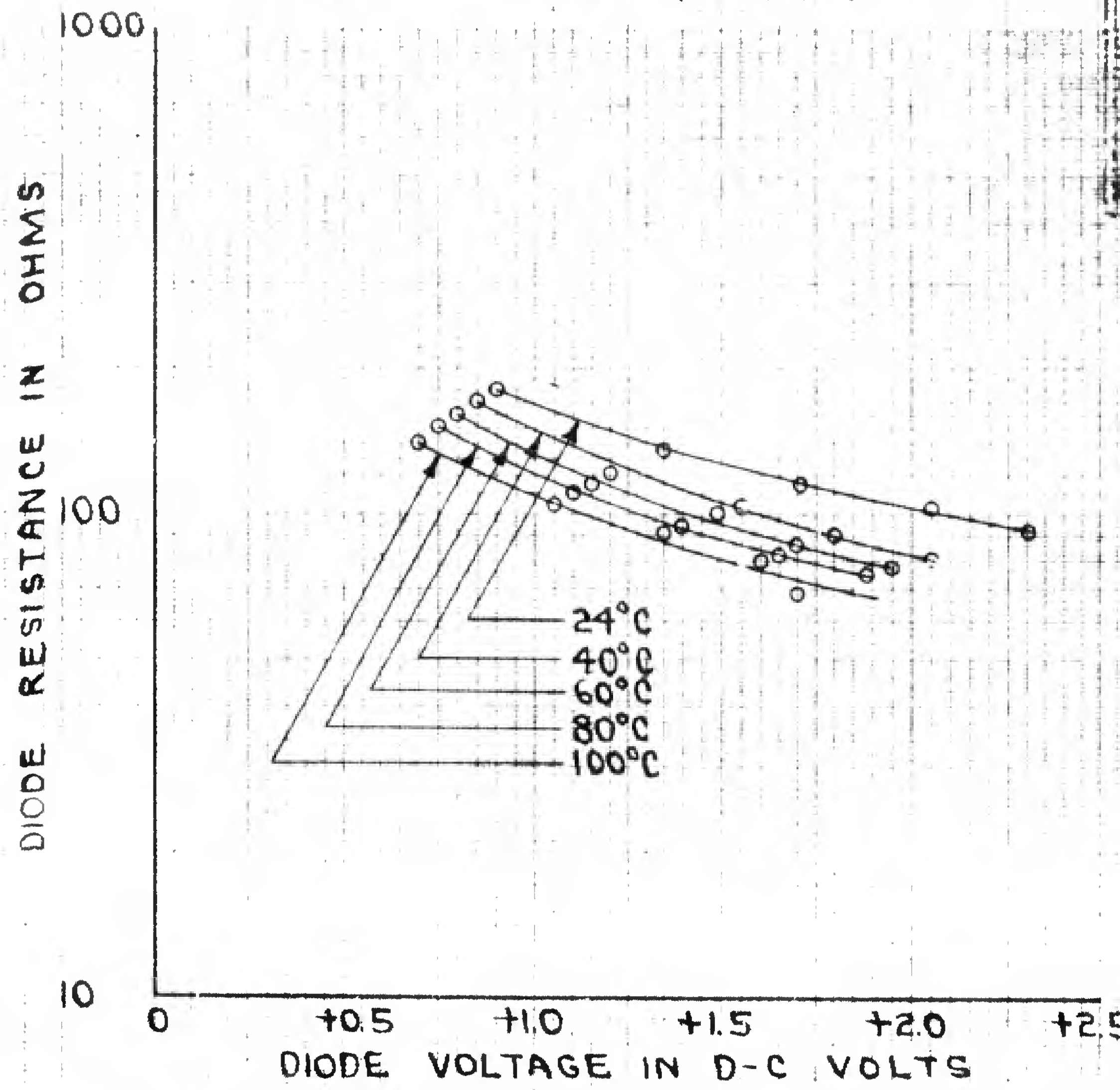
A-38166-G

6345 D.R.B. 1-30-47

RESISTANCE AS A FUNCTION OF VOLTAGE AT VARIOUS TEMPERATURES FOR SYLVANIA TYPE IN34 CRYSTAL DIODE.

DIODE NO. 2

DATA FROM 2RLE 140-143
TESTS MADE 1/14/47
TESTS BY RLE
ENGINEER IN CHARGE: DRB



FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38166-G, A-38168-G, AND A-38169-G. FOR FURTHER INFORMATION, SEE 6345 REPORT R-111.

USED IN 6345 REPORT R-111

RESISTANCE AS A FUNCTION OF VOLTAGE AT VARIOUS TEMPERATURES FOR SYLVANIA TYPE IN34 CRYSTAL DIODE.

DIODE NO. 3

DATA FROM 2RLE 140-144
TESTS MADE 1/14/47
TESTS BY RLE
ENGINEER IN CHARGE: DRB

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SERVOMECHANISMS LAB.
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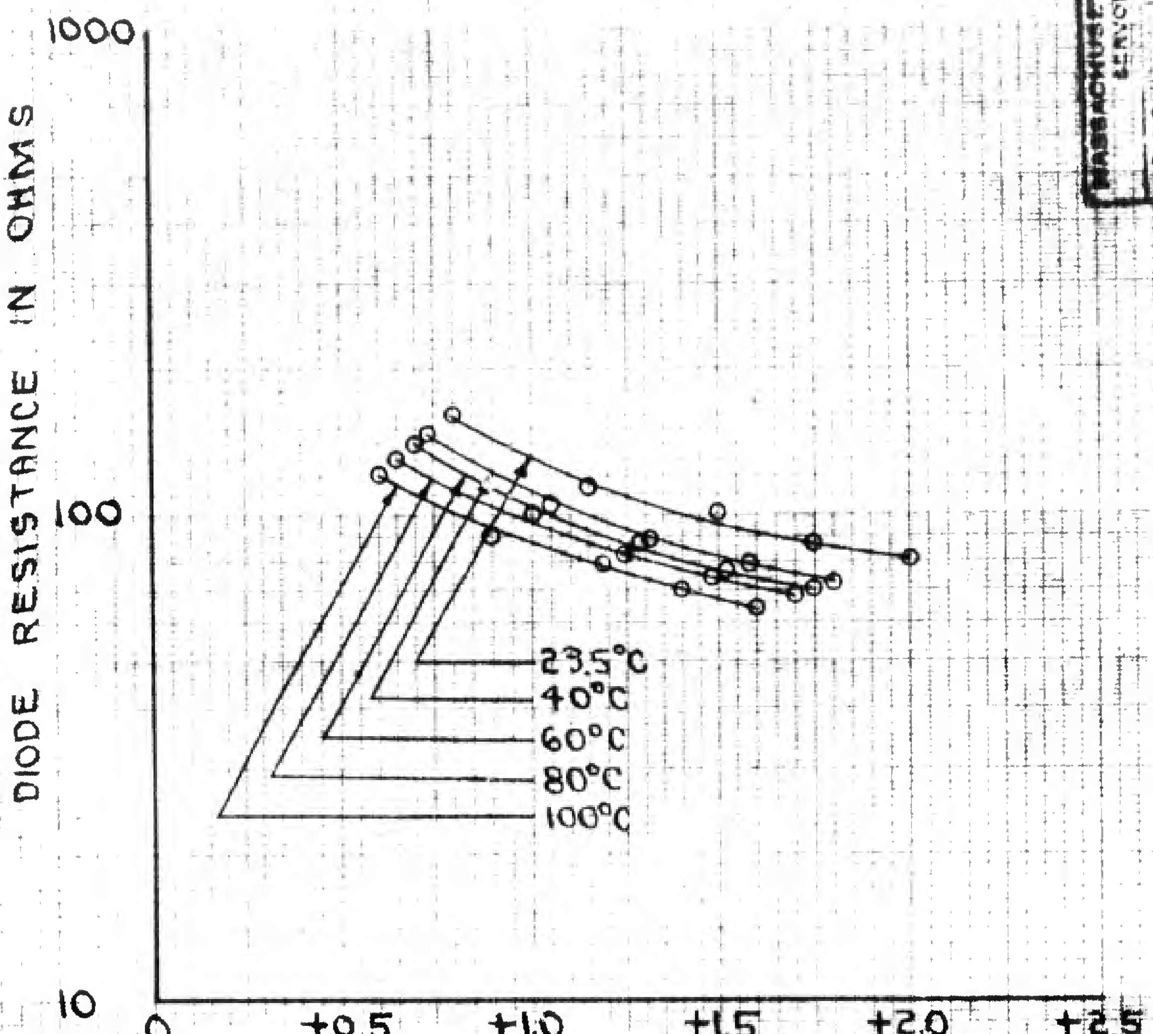
DR D.R.B. | APP.
A-38168-G



FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38166-G, A-38167-G, AND A-38169-G. FOR FURTHER INFORMATION, SEE 6345 REPORT R-111.

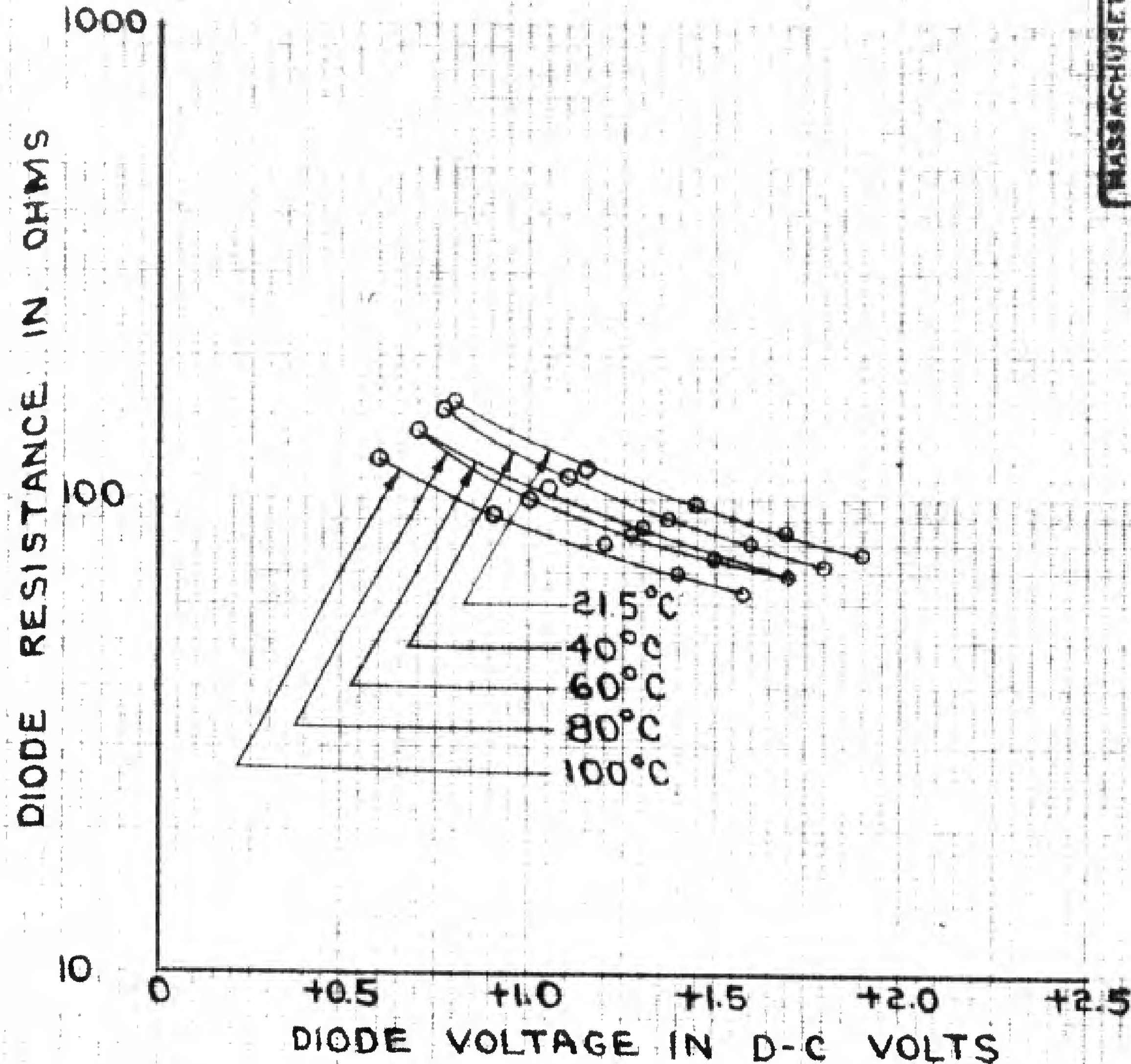
USED IN 6345 REPORT R-111

RESISTANCE AS A FUNCTION OF VOLTAGE AT VARIOUS TEMPERATURES FOR SYLVANIA TYPE IN34 CRYSTAL DIODE.

DIODE NO. 4

DATA FROM 2RLE 129-132
TESTS MADE 1/6/47
TESTS BY RLE
ENGINEER IN CHARGE: DRB

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
6345 D.R.B. D.L. 1/30/47 T. 1/31/47 A-38169-G

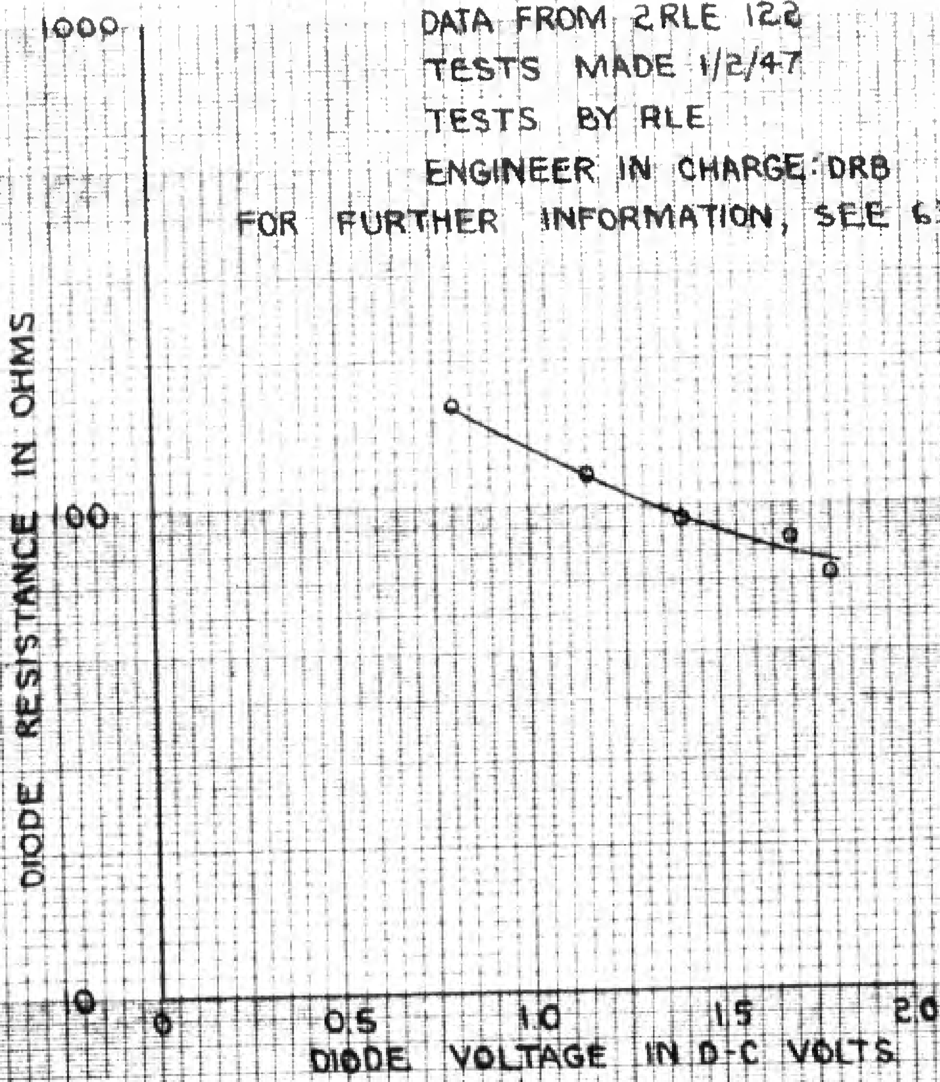


FOR SIMILAR CURVES ON THREE OTHER DIODES, SEE A-38166-G, A-38167-G, AND A-38168-G. FOR FURTHER INFORMATION, SEE 6345 REPORT R-111.

USED IN 6345 REPORT R-111

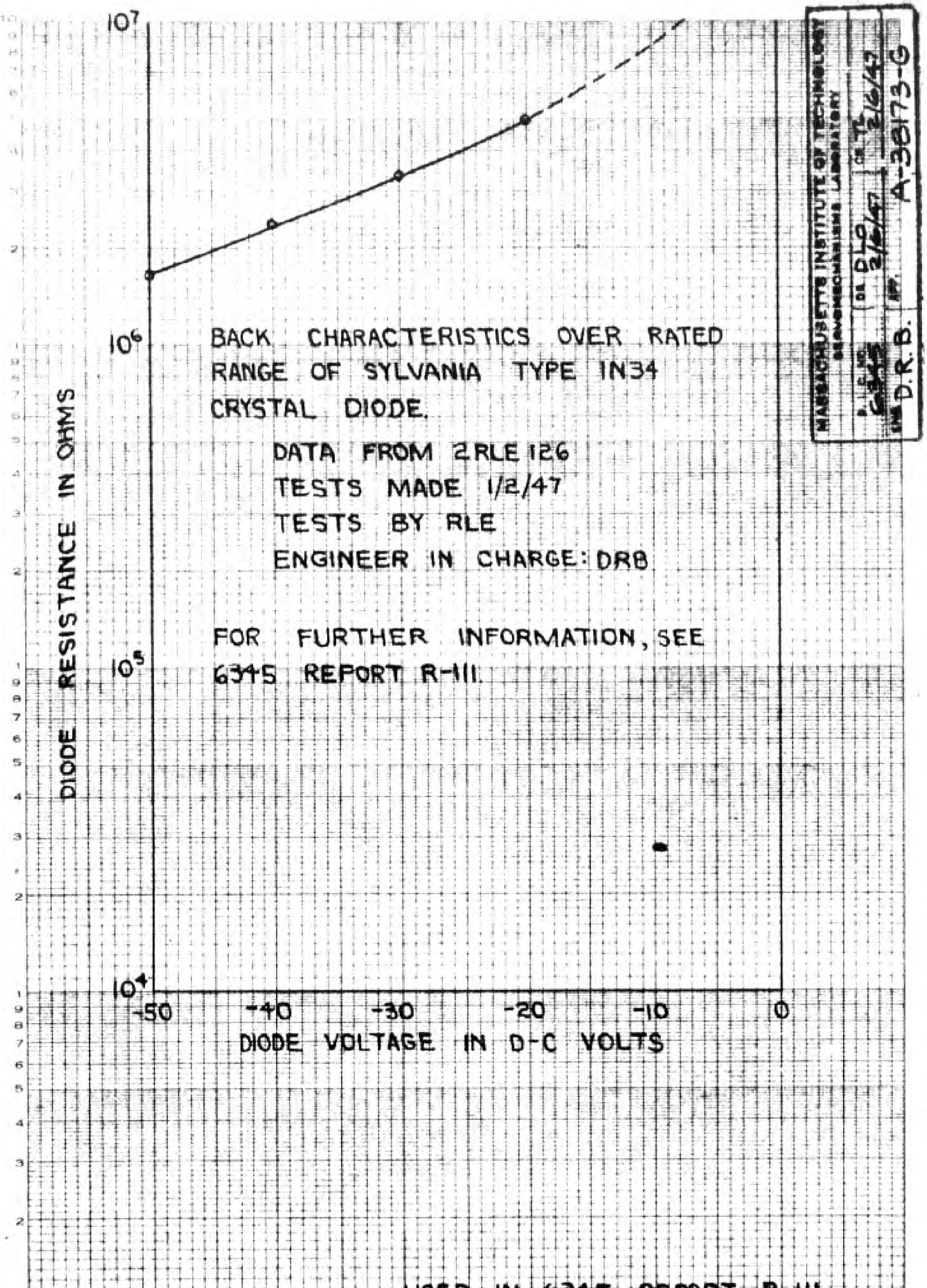
FORWARD CHARACTERISTICS OVER RATED RANGE OF SYLVANIA TYPE IN34 CRYSTAL DIODE.

DATA FROM 2RLE 122
TESTS MADE 1/2/47
TESTS BY RLE
ENGINEER IN CHARGE: DRB
FOR FURTHER INFORMATION, SEE 6345 REPORT R-111

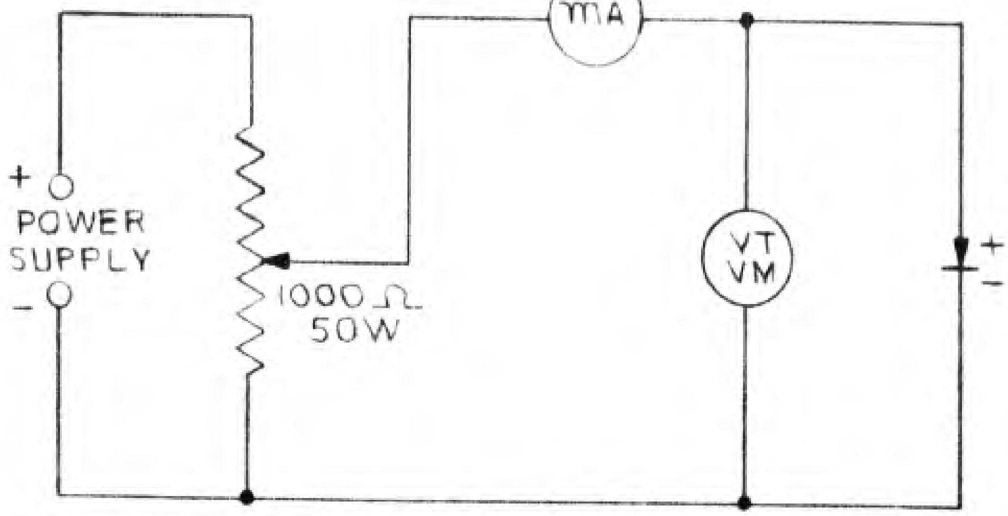


USED IN 6345 REPORT R-111

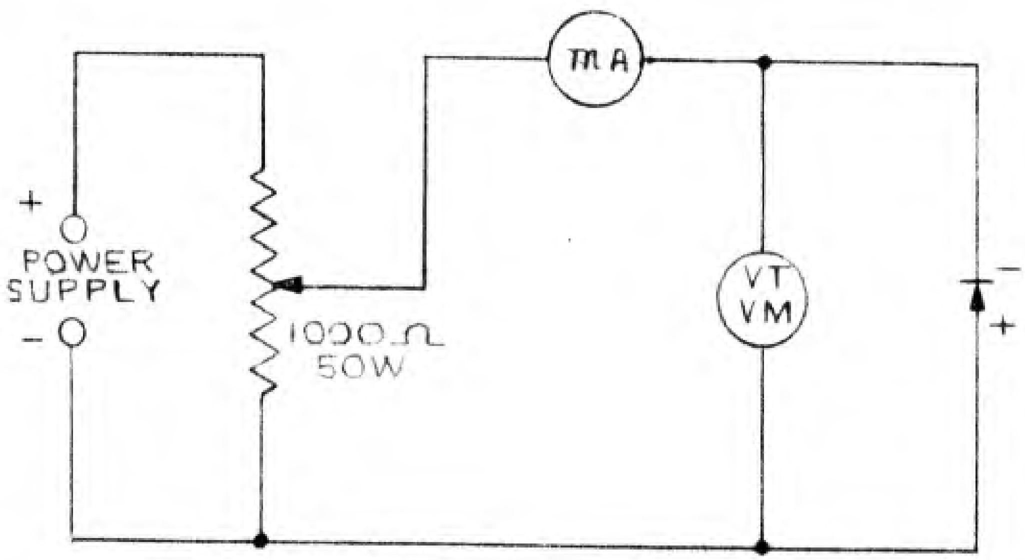
A-38172-G
D.R.B.
6345
2/6/47
2/6/47



10^7
10^6
10^5
10^4
-50
-40
-30
-20
-10
0
DIODE RESISTANCE IN OHMS
DIODE VOLTAGE IN D-C VOLTS
BACK CHARACTERISTICS OVER RATED RANGE OF SYLVANIA TYPE 1N34 CRYSTAL DIODE.
DATA FROM 2RLE 126
TESTS MADE 1/2/47
TESTS BY RLE
ENGINEER IN CHARGE: DRB
FOR FURTHER INFORMATION, SEE 6345 REPORT R-111.
USED IN 6345 REPORT R-111
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY
A-38173-G
D.R.B.



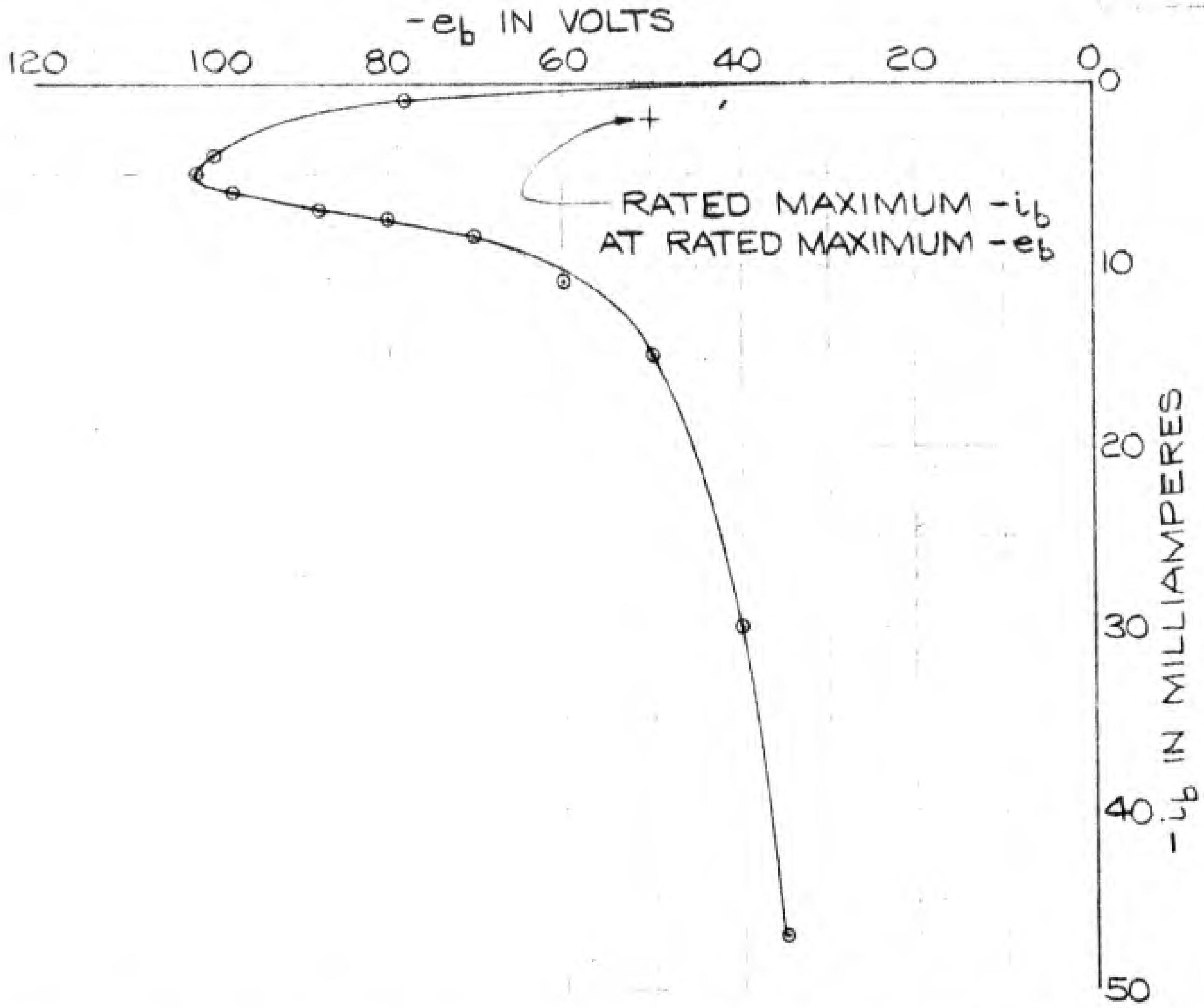
A. CIRCUT FOR FORWARD CHARACTERISTICS



B. CIRCUIT FOR BACK CHARACTERISTICS

USED IN 6345 REPORT

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY
D.I.C. NO. 6345 | DR T 4/13/47 | CK
APP | A-30476



TYPICAL IN34 CRYSTAL DIODE BACK CHARACTERISTIC

DATA FROM 1RBP9
TESTS BY RBP DATE 3/19/47
ENGINEER IN CHARGE JWF

A-30476

6345
Report No. R-108

SERVOMECHANISMS LABORATORY
Massachusetts Institute of Technology
Cambridge, Massachusetts

Date of Report: December 30, 1946

Written by: Ray L. Ellis

Drawings:
B-38147-G
B-38148-G

Subject: Characteristics of Western Electric D-172925 Crystal Rectifiers.

This report presents the characteristics of the Western Electric D-172925 crystal rectifiers based on ten crystal rectifiers ordered from Western Electric Company.

Method of Obtaining Characteristics

The circuit in Figure 1 was used to get the forward characteristic at 5, 10, 20, 30, and 40, milliamperes. The circuit of Figure 2 was used to get the forward characteristics at0.5, 1.0, 2.0, and 3.0 milliamperes. A Simpson milliammeter No. 283 was used to measure current and an RCA volt-ohmyst which had an input resistance of 9.9 megohms, was used to measure voltage in the circuit of Figure 1. An Electel 0-30-300-3000 microammeter was used to measure current and a General Electric Company decade resistor with a triplett 0-100 microammeter was used to measure voltage in the circuit of Figure 2. Correction was made for the resistance of the current measuring microammeter. Back characteristics were obtained by reversing the crystal rectifiers in the circuit of Figure 2. The multiplier and microammeter were replaced by an RCA volt-ohmyst. Resistances were computed.

Characteristics

The forward characteristics of the ten rectifiers were stable. The curves fell close to the 100-ohm constant resistance curve. The variation was about 50 ohms either side of it. The curves are shown in Graph B-38148-G.

The back characteristics were found to vary with time for some rectifiers. Six of the ten showed considerable drift; back characteristics are plotted for the other four only. No. 3 drifted so rapidly that no readings could be taken during the first minute. With eight volts across it, No. 9 showed an initial current in 1 μa. After 15 minutes, it showed a current of 55 μa. No. 6 showed a drift from 70 μa to 65 μa at -50 volts in one minute. No. 2 showed excessive drift at -50 volts. It drifted from 100 μa to 200 μa in one minute. Only one of the ten rectifiers showed no measurable drift. Graph B-38148-G shows curves for four of the ten rectifiers for negative applied voltages. Graph B-38147 shows resistance as a function of voltage over a voltage range of +5 to -50 volts. The middle curve is

TEST CIRCUITS FOR OBTAINING CHARACTERISTICS FOR THE

WESTERN ELECTRIC D-172925 CRYSTAL RECTIFIERS

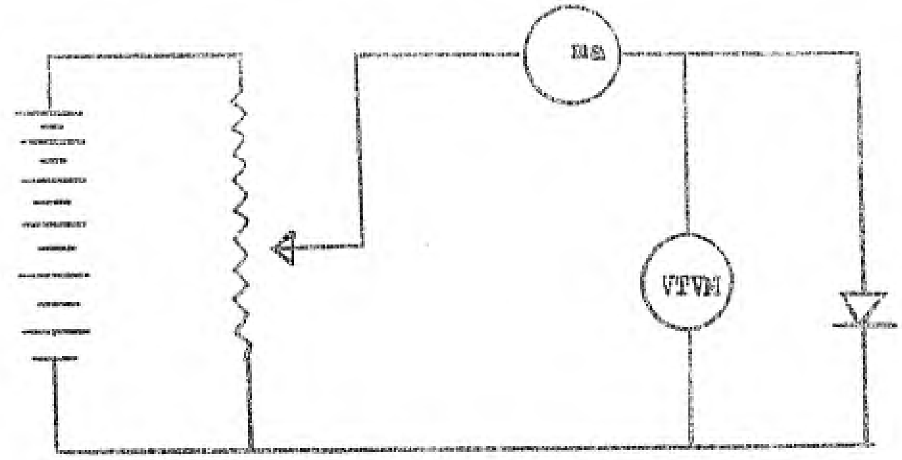


FIGURE 1 CIRCUIT DIAGRAM

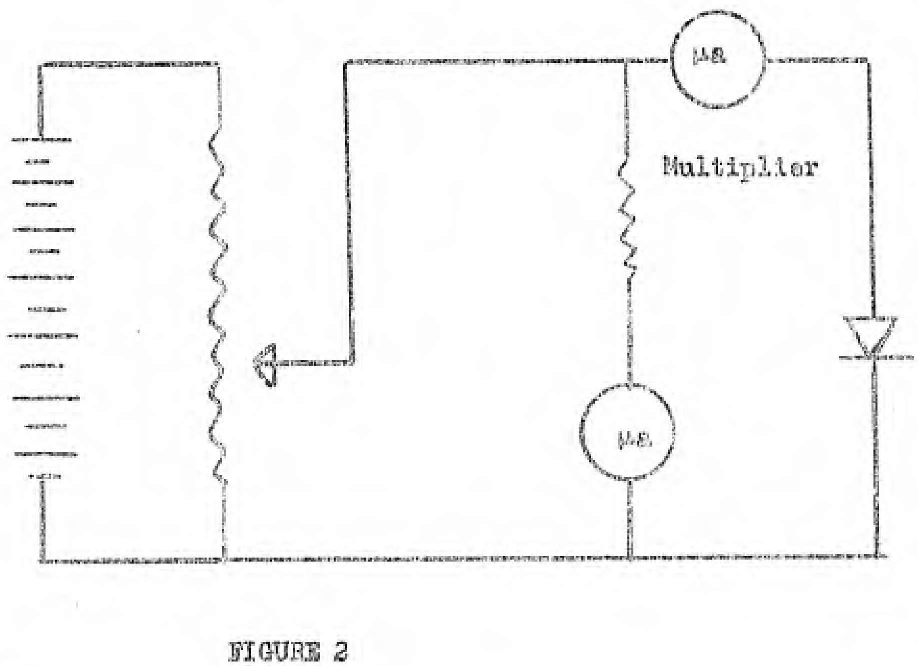


FIGURE 2

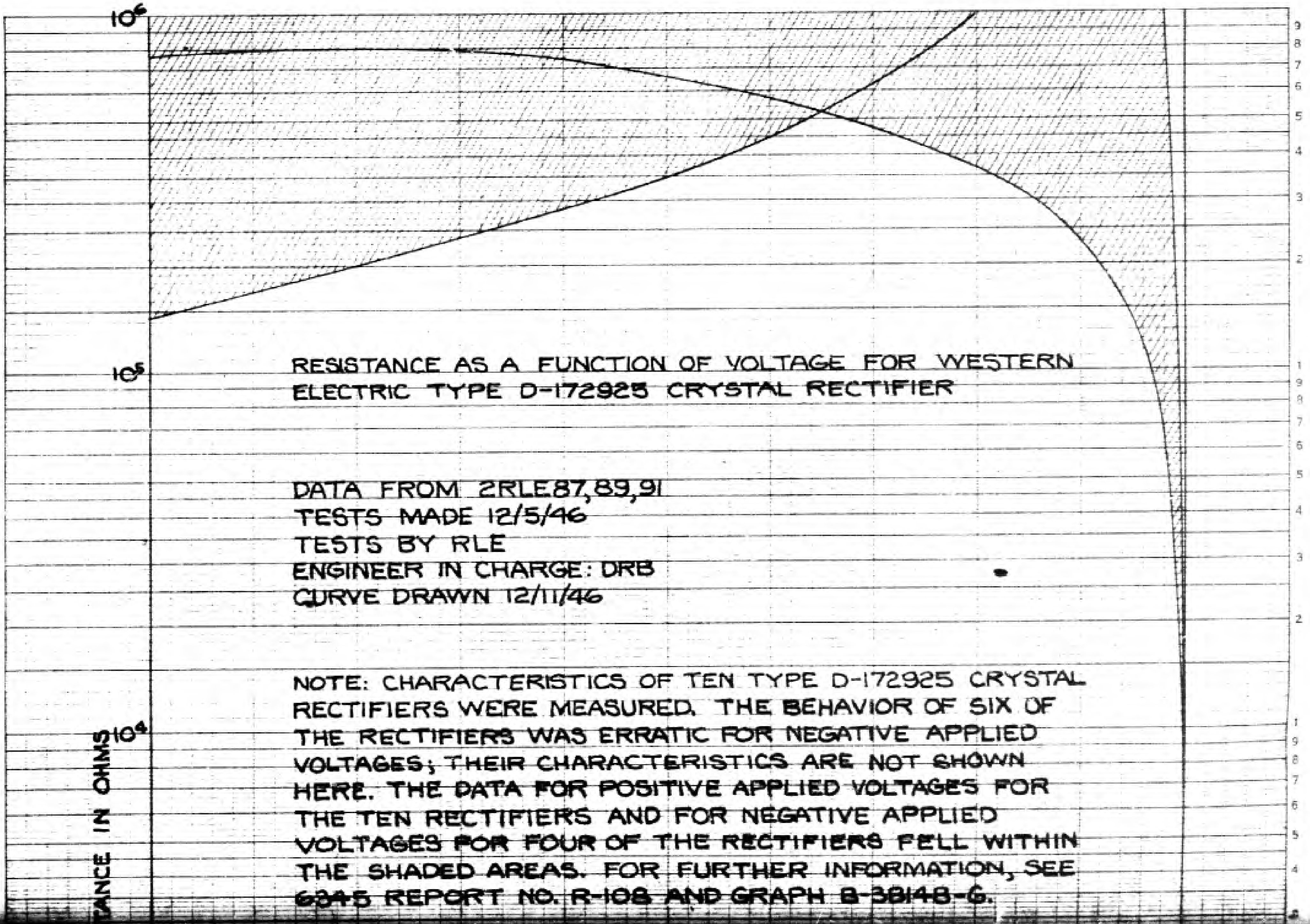
the average of the ten crystals measured.

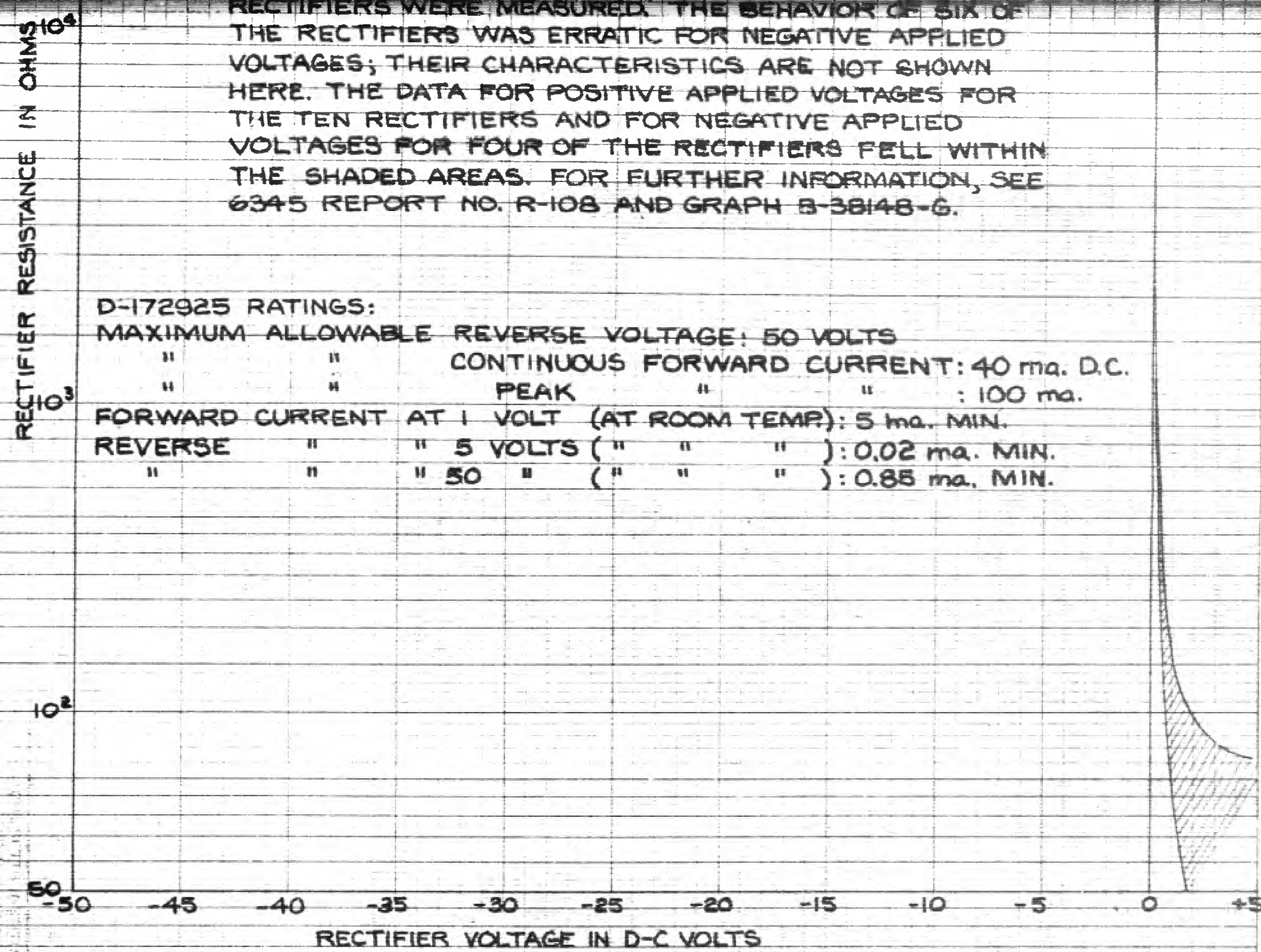
Written by: Roy R. Eccles

Engineer: David R. Brown

Approved: Jay W. Forrester

RLE:has


RESISTANCE AS A FUNCTION OF VOLTAGE FOR WESTERN ELECTRIC TYPE D-172925 CRYSTAL RECTIFIER
DATA FROM 2RLE87,89,91
TESTS MADE 12/5/46
TESTS BY RLE
ENGINEER IN CHARGE: DRB
CURVE DRAWN 12/11/46
NOTE: CHARACTERISTICS OF TEN TYPE D-172925 CRYSTAL RECTIFIERS WERE MEASURED. THE BEHAVIOR OF SIX OF THE RECTIFIERS WAS ERRATIC FOR NEGATIVE APPLIED VOLTAGES; THEIR CHARACTERISTICS ARE NOT SHOWN HERE. THE DATA FOR POSITIVE APPLIED VOLTAGES FOR THE TEN RECTIFIERS AND FOR NEGATIVE APPLIED VOLTAGES FOR FOUR OF THE RECTIFIERS FELL WITHIN THE SHADED AREAS. FOR FURTHER INFORMATION, SEE 6345 REPORT NO. R-108 AND GRAPH B-38148-6.
10^6
10^5
10^4
...ANCE IN OHMS



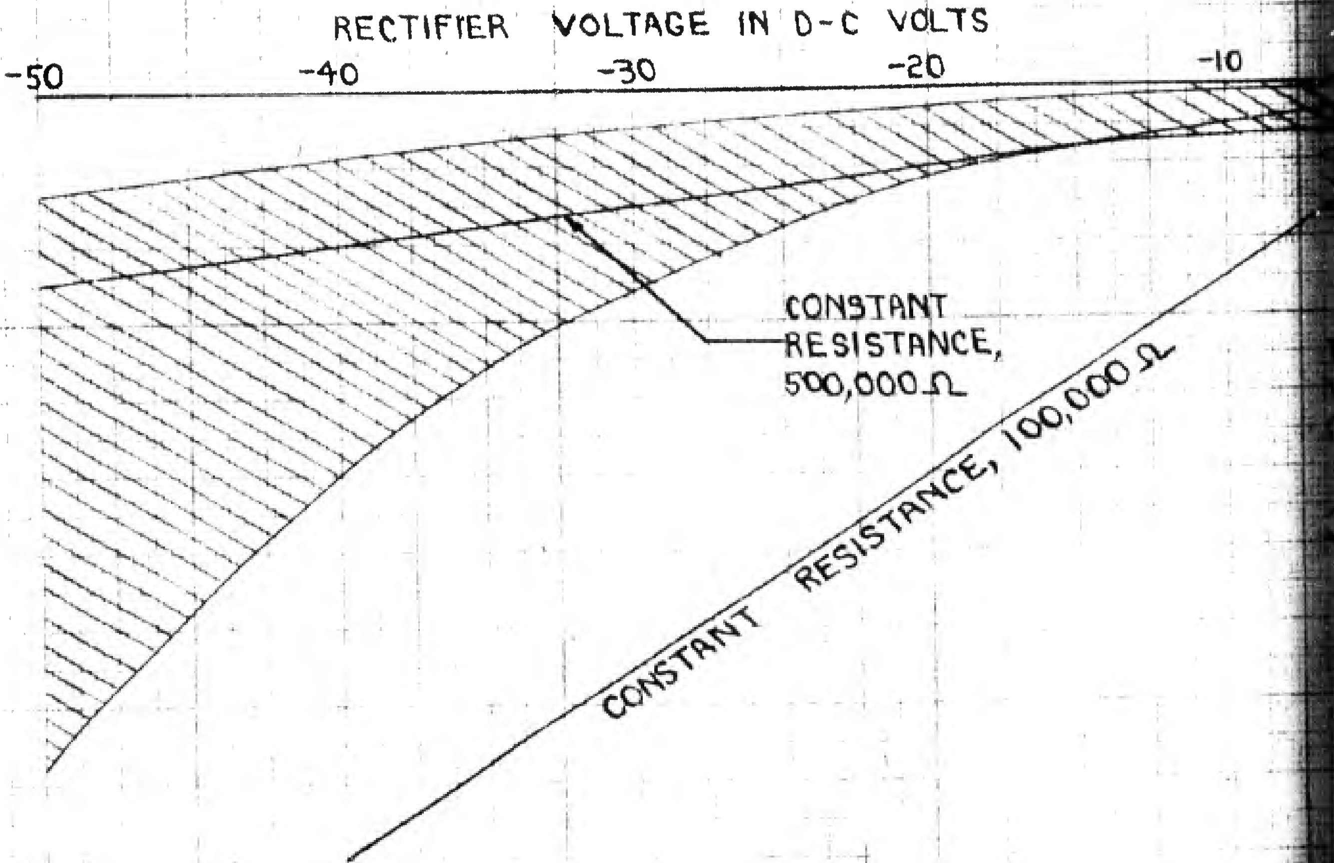
6345
D.R.B.

T.L.
12/12/46

B-38147-G

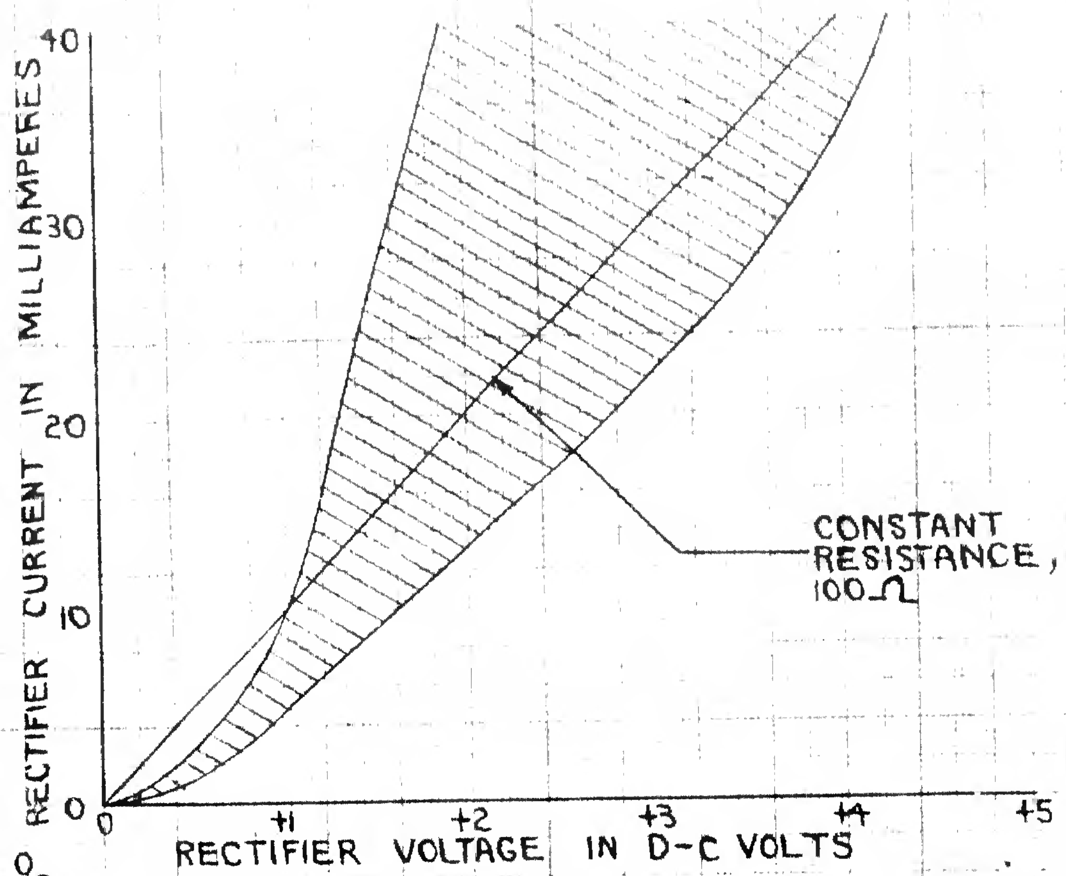
NOTE: CHARACTERISTICS OF TEN TYPE D-172925 CRYSTAL RECTIFIE[RS]
WERE MEASURED. THE BEHAVIOR OF SIX OF THE RECTIFIERS W[AS]
ERRATIC FOR NEGATIVE APPLIED VOLTAGES; THEIR CHARACTERIS[TICS]
ARE NOT SHOWN HERE. THE DATA FOR POSITIVE APPLIED VO[LTAGES]
FOR THE TEN RECTIFIERS AND FOR NEGATIVE APPLIED
VOLTAGES FOR FOUR OF THE RECTIFIERS FELL WITHIN TH[E]
SHADED AREAS. FOR FURTHER INFORMATION, SEE 6345 REPO[RT]
NO. R-108 AND GRAPH B-38148-G.

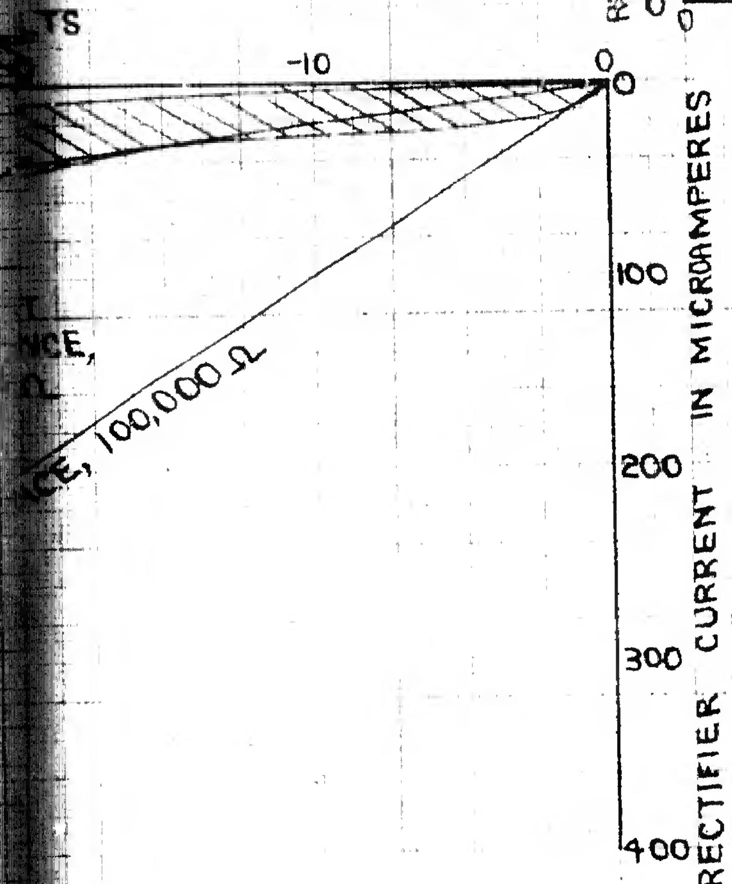
D-172925 RATINGS:
MAXIMUM ALLOWABLE REVERSE VOLTAGE: 50 VOLTS
MAXIMUM ALLOWABLE CONTINUOUS FORWARD CURRENT: 40 ma D.C.
MAXIMUM ALLOWABLE PEAK FORWARD CURRENT: 100 ma
FORWARD CURRENT AT 1 VOLT (AT ROOM TEMP): 5 ma MIN.
REVERSE CURRENT AT 5 VOLTS (AT ROOM TEMP.): 0.02 ma MIN.
REVERSE CURRENT AT 50 VOLTS (AT ROOM TEMP.): 0.85 ma MIN.



RYSTAL RECTIFIERS
E RECTIFIERS WAS
HEIR CHARACTERISTICS
VE APPLIED VOLTAGES
TIVE APPLIED
FELL WITHIN THE
SEE 6345 REPORT

TS
RRENT: 40 ma D.C.
ENT: 100 ma
P): 5 ma MIN.
MP.): 0.02 ma MIN.
MP.): 0.85 ma MIN.





TESTS MADE 12/5/46
TESTS BY RLE
ENGINEER IN CHARGE: DRB
CURVE DRAWN 12/17/46

STATIC CHARACTERISTICS OF
WESTERN ELECTRIC TYPE
D-172925 CRYSTAL RECTIFIER

MASSACHUSETTS INSTITUTE OF TECHNOLOGY SERVOMECHANISMS LABORATORY		
6345	D.L.O. 12-17-46	T.L. 12/17/46
D.R.B.	APP	B-38148-G

MEMORANDUM NO. M-[illegible]

TO: J. W. Forrester

6345

Page 1 of 2 pages

FROM: David R. Brown

SUBJECT: Talk with Sylvania on Crystal Rectifiers, January 31, 1947

DATE: February 6, 1947

A conference on crystal rectifiers was held at the Forsyth Street plant of the Sylvania Electric Products Company on the afternoon of January 31, 1947. Those present were

Mr. Dana W. Atchley, Jr.
Mr. Harold Hines
Mr. Rufus Turner
Mr. Rochester
Mr. Cornelius, of Sylvania

Dr. Morris Rubinoff of Harvard

Mr. Harris Fahnestock
Mr. L. D. Wilson
Mr. J. A. O'Brien
Mr. David R. Brown of the Servomechanisms Lab., M.I.T.

Mr. Brown and Dr. Rubinoff presented the characteristics that a crystal rectifier should have in order to be useful in a high-speed digital computer. They were in agreement on the following points. One, the back resistance must be greater than 100,000 ohms between one and fifty back volts and, at the end of one year of continuous operation, the back resistance must still be greater than 100,000 ohms over this range. Two, the maximum temperature at which this performance could be obtained should be specified by the manufacturer. Three, the cost should be low, not appreciably greater than the cost of a vacuum tube. Dr. Rubinoff thought that the rectifier should pass at least four milliamperes forward whereas Mr. Brown asked for a larger forward current, approximately twenty milliamperes.

Sylvania feels that it can meet these specifications with little difficulty. They believe that the maximum temperature will be about 50°C. At present they are developing a special crystal rectifier for Raytheon which will have a very high back resistance out to 150 back volts. This has been obtained, however, at some increase in the forward resistance. Sylvania will send us complete data on this special rectifier very soon.

Sylvania has made some tests on the 1N34. The capacitance between terminals of a rectifier in free space is evidently about 0.5 μμf. Life tests have been made at room temperature. A 500-ohm resistor is placed in

series with a rectifier and a 28-volt-rms source. A d-c output voltage of about 10 volts is measured. After 3000 hours of operation, the output voltage has not measurably changed. However, a slight drop in back resistance has been measured.

The conference concluded in an informative discussion of the properties of semiconductors led by Mr. Cornelius.

David R. Brown

David R. Brown

DRB:has

c.c. Dr. G. S. Brown
6345 Engineers
R. L. Ellis

ENGINEERING NOTES NO. E-41

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

TO: Engineers of Project 6345 — 6345

FROM: David R. Brown —

SUBJECT: Sylvania 1N38 Crystal Rectifier

DATE: June 30, 1947

The 1N38 crystal rectifier is similar to the 1N34. The principle difference is the maximum back voltage, which is 50 volts for the 1N34 and 100 volts for the 1N38. However, because the 1N38 has a higher back resistance than the 1N34 for any back voltage, it may be used where a high back resistance is desired, say 200,000 ohms, even though the back voltage never exceeds 20 volts.

For example, the clamping application requires a rectifier having greater than 100,000 ohms back resistance at 20 volts; the back voltage will not be greater than about 20 volts. A 1N38, rather than a 1N34, is recommended for this application because it will give a larger factor of safety and permit a higher ambient temperature. Also, if 1N34's were used, a large percentage of the production rectifiers would have to be rejected.

For the peaker application, a back voltage greater than 50 volts is anticipated if four rectifiers are used series-parallel; the back resistance need not be greater than 50,000 ohms. Again, the 1N38 is recommended, since the back voltage rating of the 1N34 would be exceeded.

However, 1N34's should be used wherever they are satisfactory, since the cost of a 1N38 is five times that of a 1N34.

David R. Brown
David R. Brown

DRB:has

MEMORANDUM NO. M-68

SERVOMECHANISMS LABORATORY
Massachusetts Institute of Technology
Cambridge, Massachusetts

TO: Jay W. Forrester, G. R. Brown, L. D. Wilson, S. H. Dodd, H. Fahnestock. 6345

FROM: Russell B. Palmiter

Drawings:
A-30472
A-30473
A-30474
A-30475
A-30476
A-30477

SUBJECT: Sylvania 1N34 Germanium-Crystal Diode Back Conduction Characteristics.

DATE: April 28, 1947

REFERENCES: 1RBP1-20

"Crystal Rectifiers", W. E. Stephens, ELECTRONICS, Vol. 19, No. 7, July 1946, p. 112.

"The Germanium Crystal Diode", E. C. Cornelius, ELECTRONICS, Vol. 19, No. 1, January 1946, p. 252; Vol. 19, No. 2, February 1946, p. 118.

P.B. Report No. 5200, Purdue Univ., November 1, 1944, Preparation of High Voltage Germanium Crystals.

P.B. Report No. 5201, Purdue Univ., November 1, 1944, The High Voltage Germanium Diode, Section: Experimental.

P.B. Report No. 5202, Purdue Univ., November 26, 1944, The High Voltage Germanium Rectifier, Section Two: Theoretical.

P.B. Report No. 5204, Purdue Univ., March 19, 1945, Properties of Germanium High Back Voltage Rectifier Units.

Purpose - This investigation was undertaken to observe operation of 1N34 stock samples in the back conduction direction with regard to the following:

1. Variations in transition points
2. Effect of excessive power dissipation
3. Feasibility of forced cooling of the crystal

Conclusions -

1. The shape of the 1N34 back conduction characteristic varies so greatly among units that use as a practical negative resistance element is not anticipated in their present state of development.

2. The power dissipated in the high negative current region

causes time variations in characteristics, and may be sufficient to cause loss of both negative resistance and uni-directional characteristics.

3. Temperature stability at high power dissipation cannot be achieved by practical methods of artificial cooling. It is presumed that the extremely small contact area precludes sufficient heat transfer to the cooling medium.

Discussion -

1. In a certain region of its back conduction characteristics, the germanium diode becomes a negative resistance element. (See P. B. Report 5201 and Bibliography thereto.) Thus, its reverse e_b vs. i_b characteristic is a double-valued function, and by proper choice of supply voltage and load resistance, two stable operating points may be obtained. This is illustrated in Drawings A-30472 and A-30473. In either case, as the operating point is carried outward from the origin along the characteristic curve, the load line will reach a point of tangency P_1, beyond which it must jump to a new location P_1'. As the operating point is caused to move back along the curve from P_1 to P_2, a similar action takes place from P_2 to P_3'. Points P_1 and P_2 were the primary subject of this investigation. They are herein termed the "transition" points. It should be noted that for simplicity these figures have been drawn for the two transition conditions only.

2. The 1N34 manufacturer's rating includes: Average forward anode current 22.5 ma. Back conduction 2 ma. maximum at 50 volts.

For the maximum rated back conduction the power dissipation is 0.1 watt. Taking two volts diode drop as representative for rated forward conduction of 22.5 ma. gives a dissipation of 0.045 watt. Therefore, powers greater than 0.1 watt are herein considered "high" or "abnormal". Reference to the typical back characteristic of Drawing A-30476 shows that beyond P_1 the power dissipation may greatly exceed these values, ranging approximately from 0.5 to 1.5 watt.

Procedure -

1. The circuit used in shown in Drawing A-30474. Transition points were observed by varying E_{bb} with a constant load resistance of 10,000 ohms. Comparison between units was made on the basis of e_{b1} and e_{b2} observed for a number of 1N34's taken at random from stock. Readings were taken as quickly as possible, with momentary power application to prevent drift due to heating.

One complete characteristic was taken. Forward conduction was observed as described above. The back conduction was obtained with both

E_{bb} and R_L variable, to obtain points in the region from P_3 to P_1.

2. The effect of increased crystal temperature due to abnormal power inputs was observed. Characteristic curves at elevated temperatures were not of primary interest and were not taken due to the difficulty in maintaining and measuring temperature of the contact area on the crystal face.

3. Artificial cooling was used in an attempt to obtain stable operation in the high power region, where temperature variations were severe. The media employed included air jet, carbon tetrachloride (at 2°C.) packed in ice, and Reagent alcohol (at -70°C.) packed in dry ice. The media were applied externally to the diode cartridge, and directly to the crystal surface.

<u>Results</u> -

1. One typical reverse characteristic is shown in Drawing A-30476. The forward characteristic for the same diode also is given in Drawing A-30477.

Data on the spread of transition points among units is given in Tables I and II. Data for the 2°C. temperature are not shown. The difference between this and ambient temperature was not significant compared with the -70°C. condition. However, there was a measurable increase in forward and reverse resistances and in the transition voltages for any one unit when taken from ambient temperature to 2°C.

2. Drawing A-30475 shows the change in characteristics inferred from observations made with high power inputs. After short power applications, the characteristic curves tended to return to near their original shapes when the crystal was allowed to cool. Power of about 1.0 watt applied for several minutes caused a permanent change, as from curve 1 to curve 3, Drawing A-30475. Somewhat greater power input resulted in essentially complete loss of negative resistance, as Curve 5, Drawing A-30475, and was accompanied by about 10% increase in forward resistance and as much as 90% drop in back resistance. Some samples showed a drop of about 10% in e_{b1} after the first transition, after which they remained constant until the unit experienced higher dissipation or longer power applications.

3. All forced cooling methods tried changed the diode characteristics, as evidenced by increased forward and reverse resistance and higher values of e_{b1}, when a unit was taken from ambient temperature (22°C) to the lower temperature. As would be expected, the greatest change in characteristics was noted for the -70°C case. Tables I and II permit comparison of transition point voltages between ambient temperature and -70°C. At the temperature of -70°C, two units of the five tested showed two high voltage transition points, indicating that their characteristics were triple or quadruple valued functions over a range of one or two volts in e_b.

Units which were opened to introduce the cooling liquids directly to the crystal were observed to cause bubbling of the liquid at the point of contact between whisker and crystal when high power input was applied. It might, therefore, be presumed that the contact area reaches temperatures at least as high as 78°C. Although there was considerable difference in the behavior of individual units, none exhibited good stability at high power inputs with any cooling method employed.

See Drawing A-30472	MAX.	MIN.	AVE.	Within ± 10% of Average NO.	Within ± 10% of Average %
e_{b_1}	215	70	115	9	50
e_{b_2}	120	58	84	7	39
Δe_b	95	12	32	2	11

TABLE NO. 1

Eighteen 1N34 diodes at Room Temperature(22-23°C)

See Drawing A-30472	MAX.	MIN.	AVE.	Within ± 10% of Average NO.	Within ± 10% of Average %
e_{b_1}	226	130	163	0	0
e_{b_2}	130	110	134	0	0
Δe_b	74	15	29	0	0

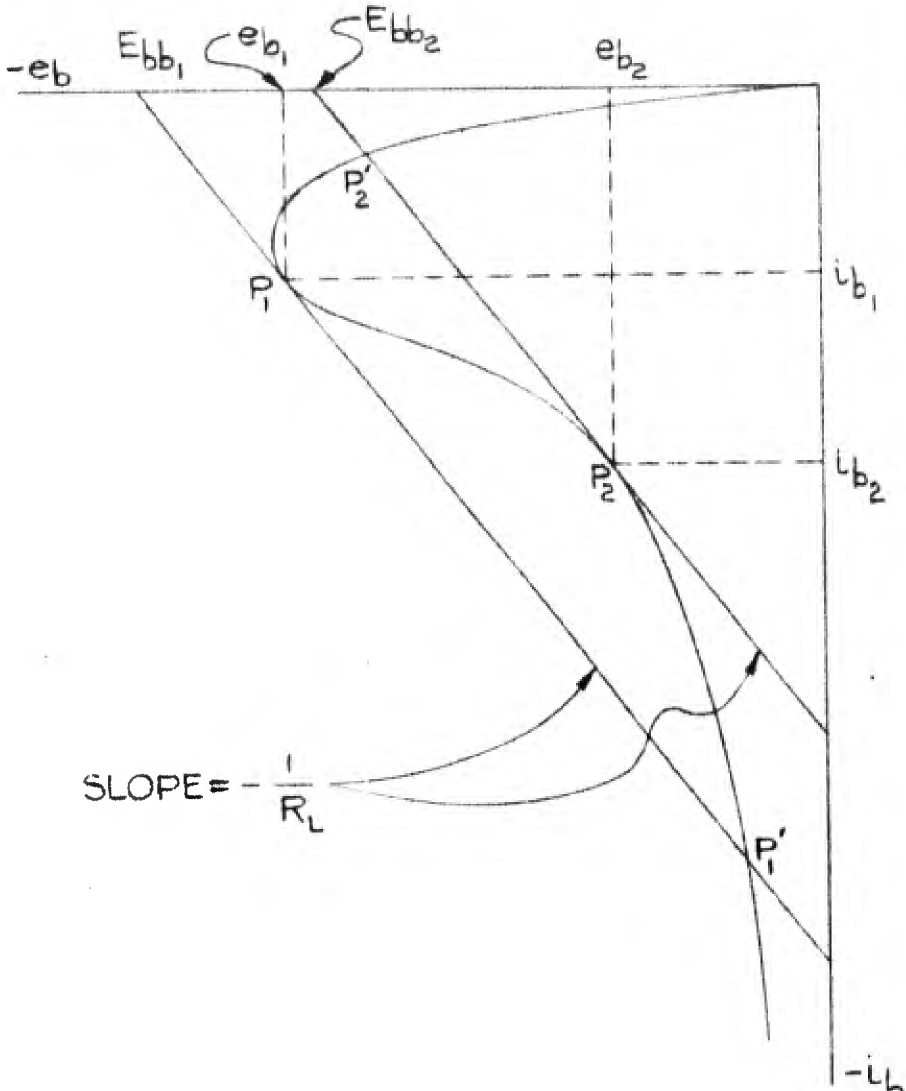
TABLE NO. II

Five 1N34 diodes in Reagent alcohol at -70°C.

Russell B. Palmiter

Russell B. Palmiter

RBP:has

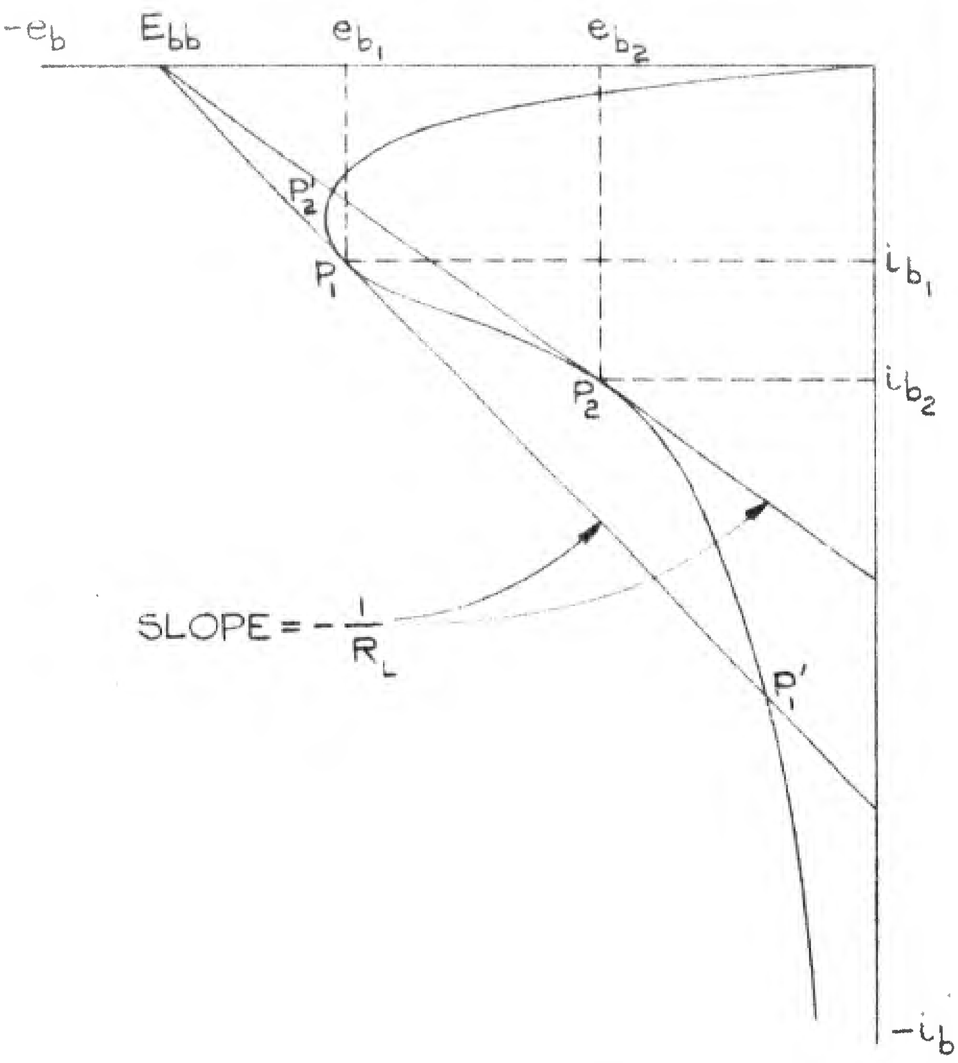


IN34 CRYSTAL DIODE BACK CHARACTERISTICS

ILLUSTRATING TRANSITION BETWEEN TWO OPERATING POINTS OBTAINED BY VARYING E_{bb} WITH CONSTANT R_L

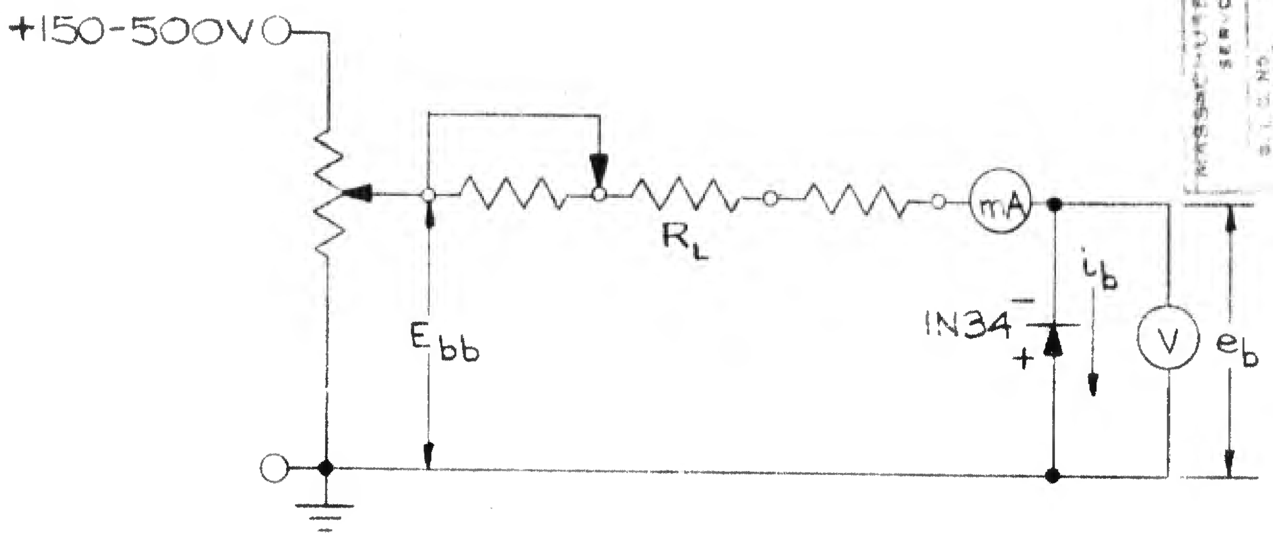
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY
6345 TL 4/18/47
A-30472

A-30472



IN34 CRYSTAL DIODE BACK CHARACTERISTICS

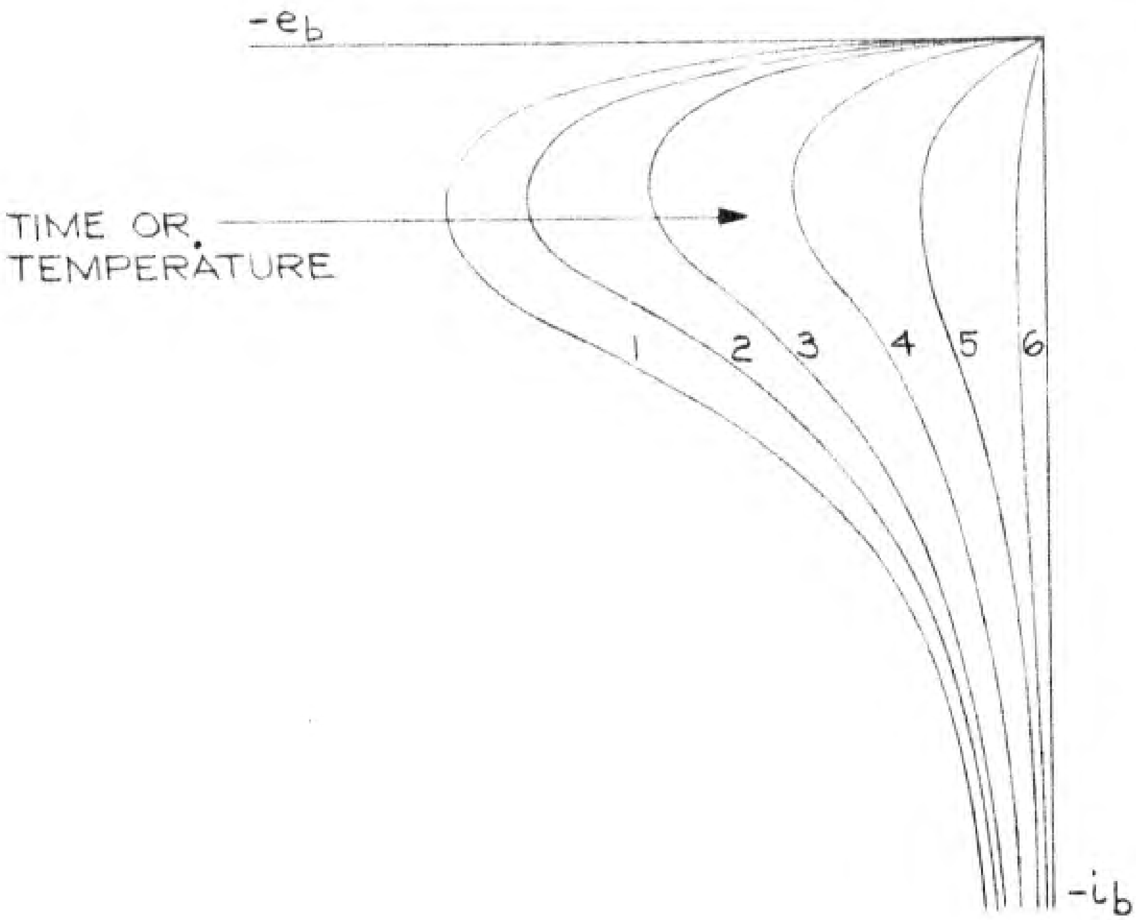
ILLUSTRATING TRANSITION BETWEEN TWO OPERATING POINTS OBTAINED BY VARYING R_L WITH CONSTANT E_{bb}



mA = SIMPSON VOLT-OHM-MILLIAMMETER, MODEL 260 (SM-3435)
V = VOLTOHMYST (SM-660)
R_L = 10,000Ω TO 1.0375 MEG IN 16 STEPS
E_{bb} = 0 TO 500V

TEST CIRCUIT FOR MEASURING BACK CHARACTERISTICS OF IN34 CRYSTAL DIODE

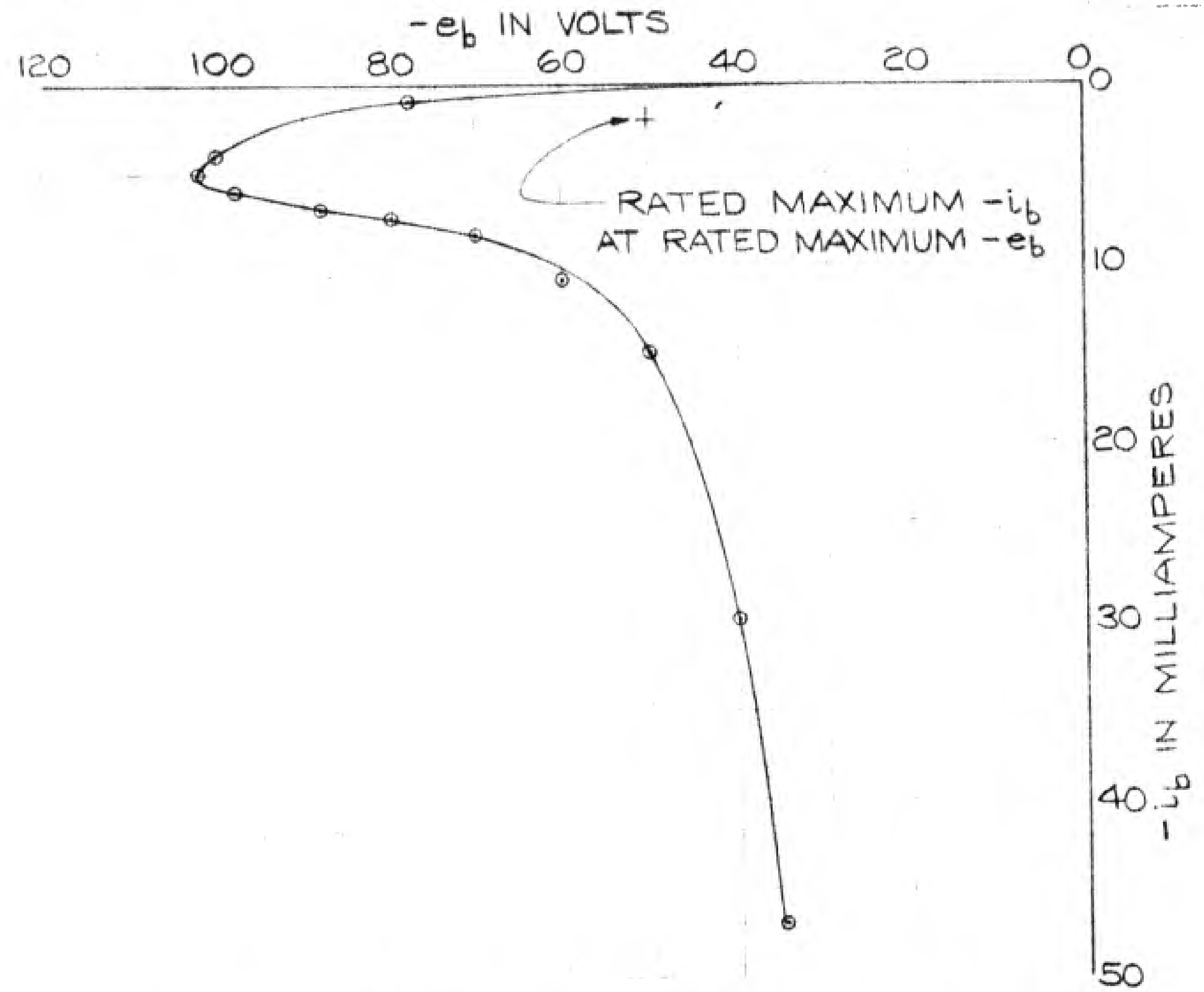
A-30474



IN34 CRYSTAL DIODE BACK CHARACTERISTICS

INFERRED CHANGE IN CHARACTERISTICS WITH INCREASING TEMPERATURE, OR WITH TIME AT EXCESSIVE POWER DISSIPATIONS.

A-30475

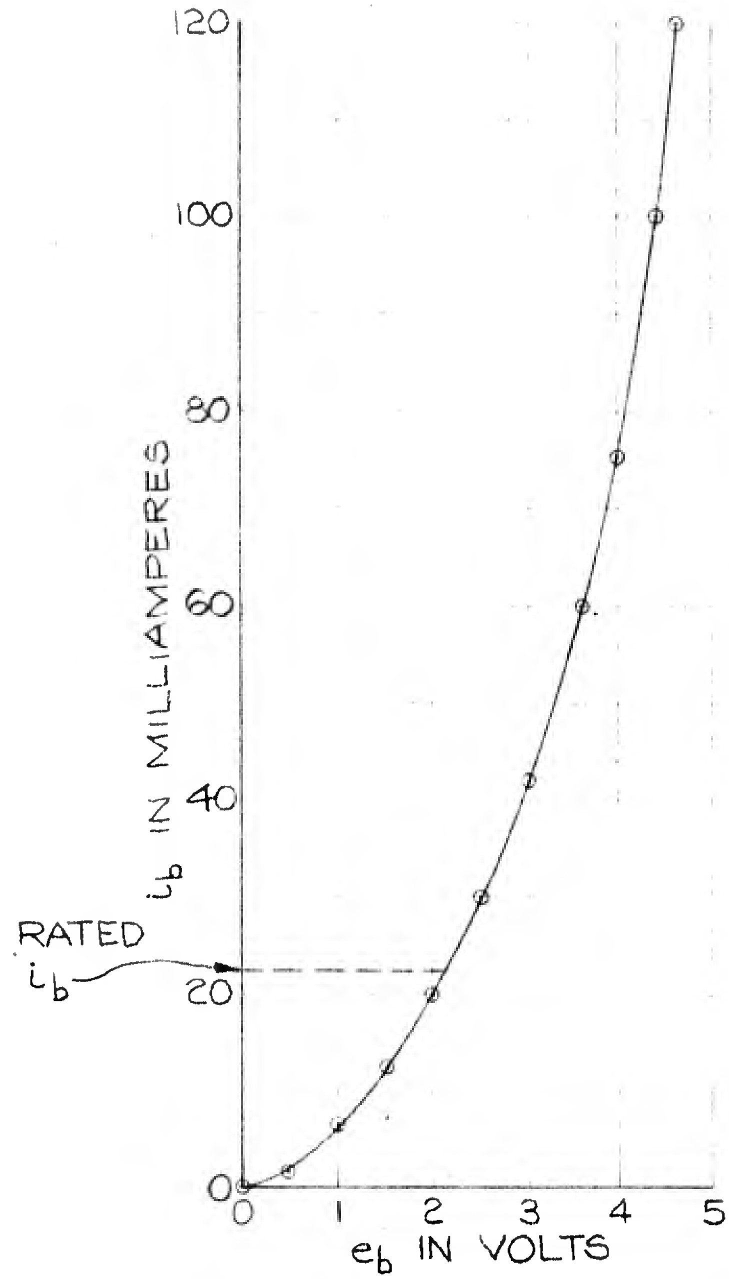


TYPICAL IN34 CRYSTAL DIODE BACK CHARACTERISTIC

DATA FROM LRBP9
TESTS BY RBP DATE 3/19/47
ENGINEER IN CHARGE JWE

...USETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY
D.I.C. NO. 6345 DR TL 4/13/47 CK
ENG APP A-30476

A-30476



NOTE: DIODE BURNED OUT AT ABOUT 200 ma, 4.7 V

TYPICAL 1N34 CRYSTAL DIODE FORWARD CHARACTERISTIC

DATA FROM 1RBP9

TESTS BY RBP DATE 3/19/47

ENGINEER IN CHARGE JWF

A-30477

ENGINEERING NOTES E-37

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

Illustrations:
B-30465-2
SA-39225

To: 6345 Engineers

From: David J. Crawford

Subject: Model 1 Crystal Tester

Reference: A. 2DJC 3-8 inclusive
B. 3RLE 30, 31, 42 and 43

Date: June 17, 1947

I. General Description

The Model 1 Crystal Tester is a device to facilitate rapid checking of 1N34 crystal diodes. It will measure the forward resistance with an applied potential of +1 volt, and the back resistance at potentials of -1 and -50 volts.

The present standards consider a crystal to be good if the forward resistance is less than 200 ohms at +1 volt, and the back resistance is greater than 0.1 megohm at -1 and -50 volts. The meter scale of the instrument is calibrated with GOOD-BAD areas to rapidly indicate if a crystal meets the standards. Numerical scales are also included so that the actual crystal resistance may be noted.

II. Circuit Description

The circuit consists of a regulated d-c power supply and a vacuum-tube voltmeter. (See drawing B-30465-2). During a test, a known voltage in series with a precision resistor is applied to the crystal. The vacuum-tube voltmeter measures the voltage drop across the resistor or the crystal (depending upon the polarity of the measurement) and is calibrated in terms of resistance.

Equivalent circuits for the three measurements are shown in SA-39225. The voltmeter circuit is arranged so that the meter deflection is at full-scale with no voltage applied, and reads one-half scale for -1 volt input. An inspection of the circuits in the drawing shows that if the crystal diode has a 200-ohm forward resistance and a 0.1 megohm back resistance, the voltmeter will have -1 volt applied to its input for all three cases and the pointer will be at mid-scale.

The regulated power supply consists of a half-wave selenium rectifier circuit that supplies voltage to an OB2 gaseous regulator tube. A voltage divider is used to supply a potential of -2 volts with an effective source resistance of 200 ohms, and -52.25 volts with a source resistance of 2,500 ohms.

The current through the bleeder may be adjusted by the VOLTAGE ADJ rheostat. When it is correctly adjusted to 10 milliamperes, 2 volts will appear across the 200-ohm precision resistor. When this adjustment has been correctly made, the -50 VOLT ADJ potentiometer may be adjusted to have an open-circuit voltage of -52.25 volts.

The vacuum-tube voltmeter is a series-balance bridge that operates directly from the a-c voltage supplied by the power transformer. The bridge balance is controlled by the RIGHT ADJ rheostat, and the meter sensitivity is controlled by the LEFT ADJ.

III. Initial Adjustment

When the unit is initially built, the VOLTAGE ADJ and -50 VOLT ADJ controls must be set correctly. First, the tester should be connected to a 115-volt, 60-cycle a-c supply, and turned on for at least five minutes to reach operating temperature. A voltmeter should be connected across the crystal test terminals of the unit. The VOLTAGE ADJ control should be adjusted first, and the adjustment should be made with the scale knob set to scale A. The open-circuit voltage should be 2 volts, and the effective resistance of the source is 200 ohms. If a 1,000 ohms-per-volt meter is used on its 3-volt scale, this means that the VOLTAGE ADJ control should be varied until the meter reads 1.875 volts. The meter should have a relatively high accuracy (±1% or better) as the accuracy of the tester is dependent upon these adjustments.

When the above adjustment has been made, the -50 VOLT ADJ control may be set. With the meter still across the test terminals, the scale knob should be turned to scale C. The open-circuit voltage, after adjustments have been made, should be 52.25 volts and the source resistance is 104,500 ohms. If a 1,000 ohm-per-volt meter is being used on its 100-volt scale, the control should be adjusted so that the meter reading is 25.5 volts.

If a meter is used which has a resistance different from 1,000 ohms-per-volt, or a meter scale different from the one specified, the correct meter readings will have to be calculated from the above information.

There is an alternate method of adjusting the -50 VOLT ADJ that makes use of the voltmeter in the tester, and a 0.1 megohm precision resistor. After the VOLTAGE ADJ control has been set, it is possible to calibrate and balance the voltmeter circuit. With the test terminals empty and the scale knob on scale C, the RIGHT ADJ knob should be set so that the meter pointer is on the mark at the right-hand end of the scale. After this adjustment has been made, the scale knob should be turned to scale A, and the LEFT ADJ control set so that the pointer is on the mark at the left-hand end of the meter scale.

When the meter has been adjusted, the 0.1 megohm precision resistor should be placed across the test terminals and the scale knob set on scale C. The -50 VOLT ADJ control should be set so that the meter pointer is on the mid-scale mark. This method of adjustment is frequently more accurate than the first method described if the accuracy of the calibrating voltmeter is not very high.

IV. Operating Procedure

After the tester has been allowed to reach operating temperature, the meter adjustments should be checked. With the scale knob on scale C, the RIGHT ADJ knob should be set so that the pointer is on the mark at the right-hand end of the scale. After this adjustment has been made, the scale knob should be turned to scale A, and the LEFT ADJ control set so that the pointer is on the mark at the left-hand end of the meter scale. The unit is now ready for use.

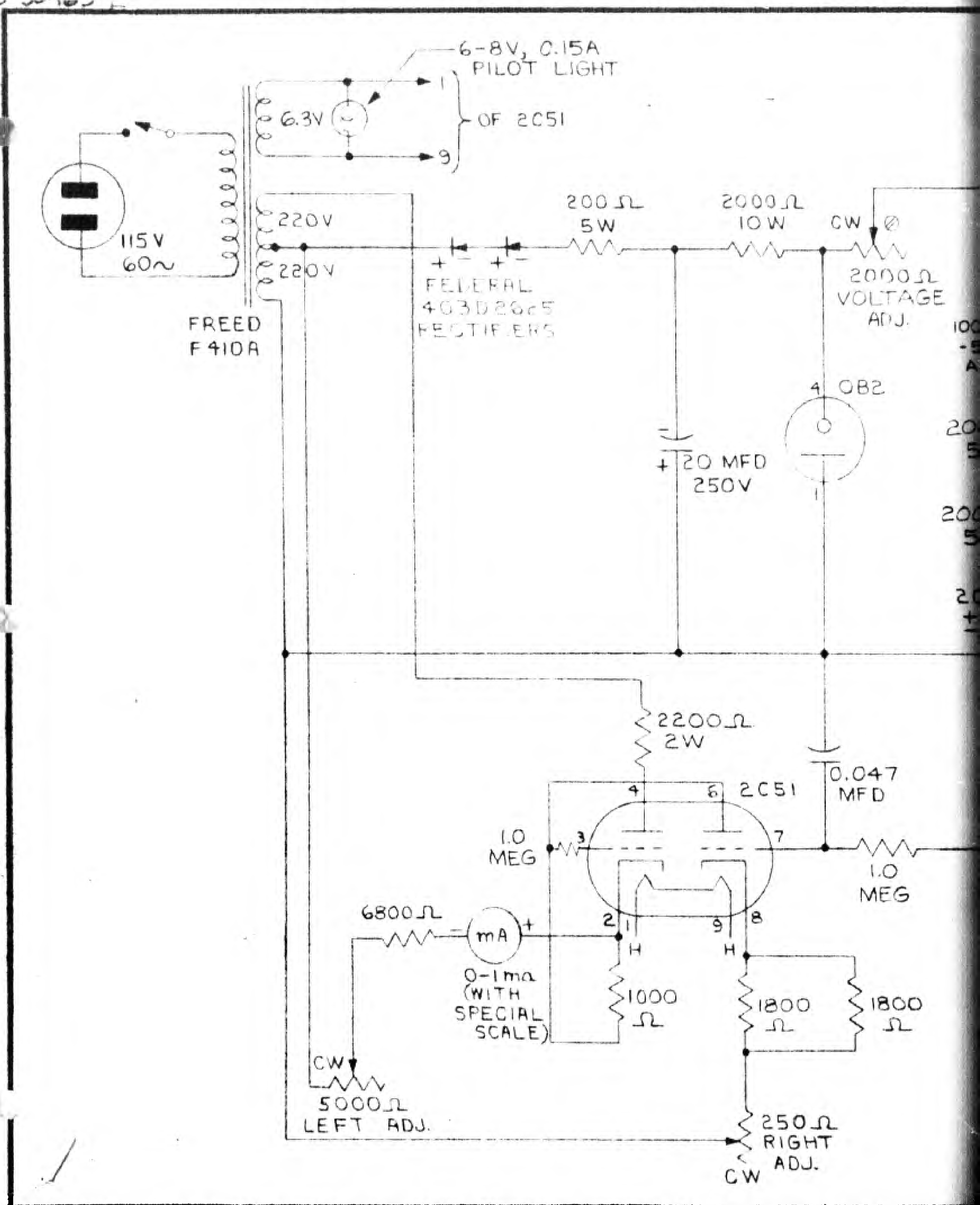
The crystal to be tested should be place in the test terminals so that the polarity markings on the crystal correspond to those of the terminals. The meter readings should be noted for the scale knob on positions A, B, and C, and if the meter pointer is in the BAD section of the scale for any reading, the crystal has failed to meet the specifications. The numerical scales will indicate the actual crystal resistance, if it is within the range of the instrument.

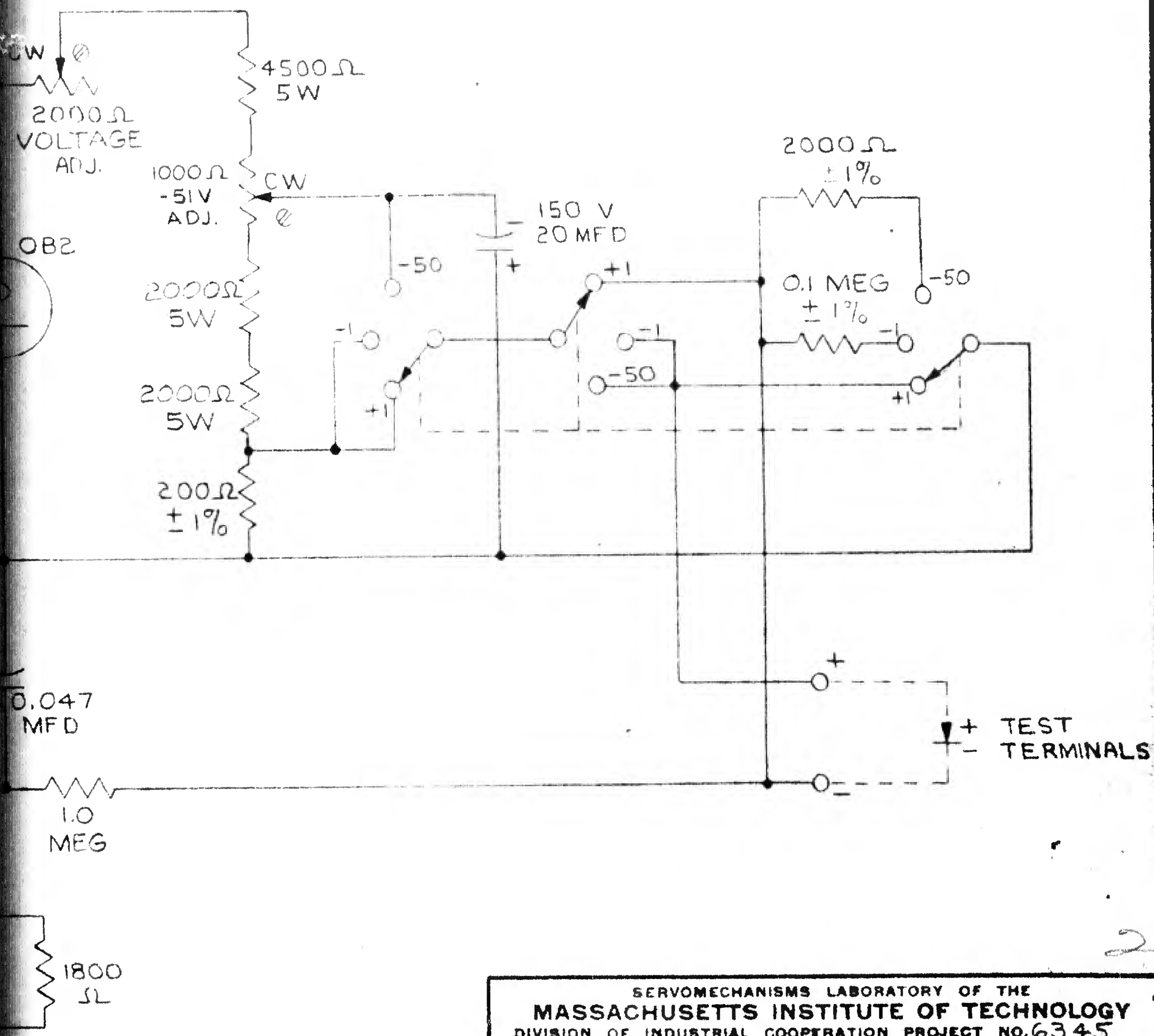
V. Results

In a batch of 100 new crystals that were tested, approximately 25% failed to meet the specifications. This percentage of rejects has been verified by tests on other groups of new crystals. It is possible that the standards may have to be lowered so that the initial reject rate will not be so high. If the standards are changed, a new meter scale would probably be necessary if the GOOD-BAD markings on the scale are to remain significant.

David J. Crawford

DJC:vh


6-8V, 0.15A
PILOT LIGHT
6.3V
1
9
OF 2C51
115V
60~
220V
220V
FREED
F410A
FEDERAL
403D2625
RECTIFIERS
200 Ω
5W
2000 Ω
10W
CW
2000 Ω
VOLTAGE
ADJ.
4
OB2
1
20 MFD
250V
2200 Ω
2W
4
6
2C51
0.047
MFD
1.0
MEG
3
7
1.0
MEG
2
1
9
8
H
H
6800 Ω
mA
0-1ma
(WITH
SPECIAL
SCALE)
1000
Ω
1800
Ω
1800
Ω
CW
5000 Ω
LEFT ADJ.
250 Ω
RIGHT
ADJ.
CW

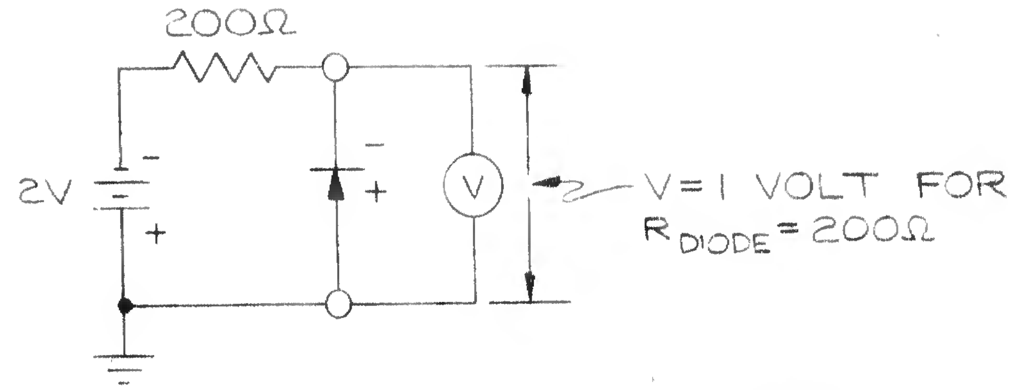


SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO. 6345

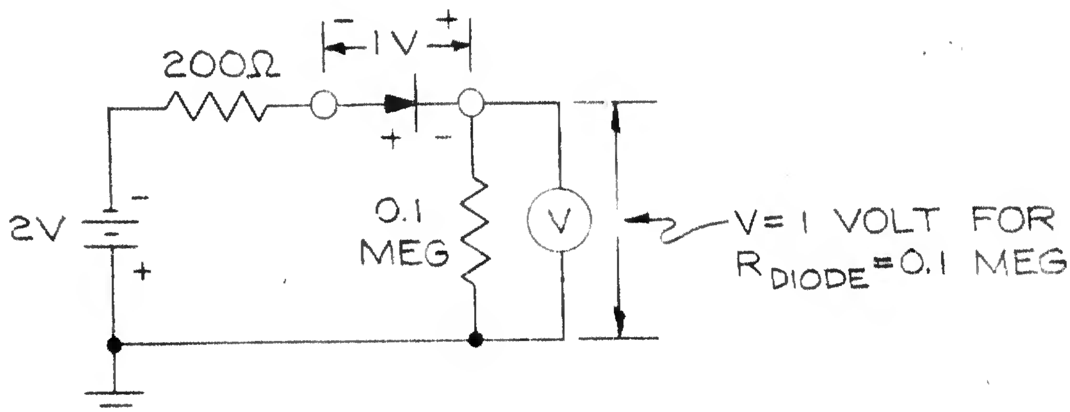
SCHEMATIC, CRYSTAL TESTER, MODEL I

SCALE:	DR D.L.O. 4-11-47		B-30465-2
ENG. DJC	CK. JL 4/11/47	APP.	

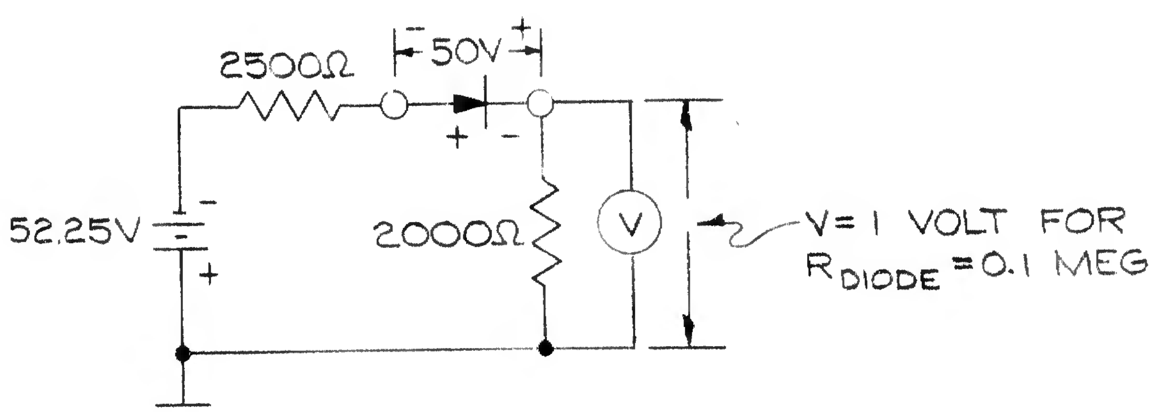
2



SCALE A – FORWARD MEASUREMENT
(PLUS 1 VOLT APPLIED)



SCALE B – BACK MEASUREMENT
(MINUS 1 VOLT APPLIED)



SCALE C – BACK MEASUREMENT
(MINUS 50 VOLTS APPLIED)

CRYSTAL TESTER
EQUIVALENT CIRCUITS

6345 5/22/47 SA-39225

SA-39225

MEMORANDUM M-92

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

To: 6345 Engineers — 6345

From: David J. Crawford — Page 1 of 1

Subject: Changes of Model 1 Crystal Tester

Date: July 28, 1947

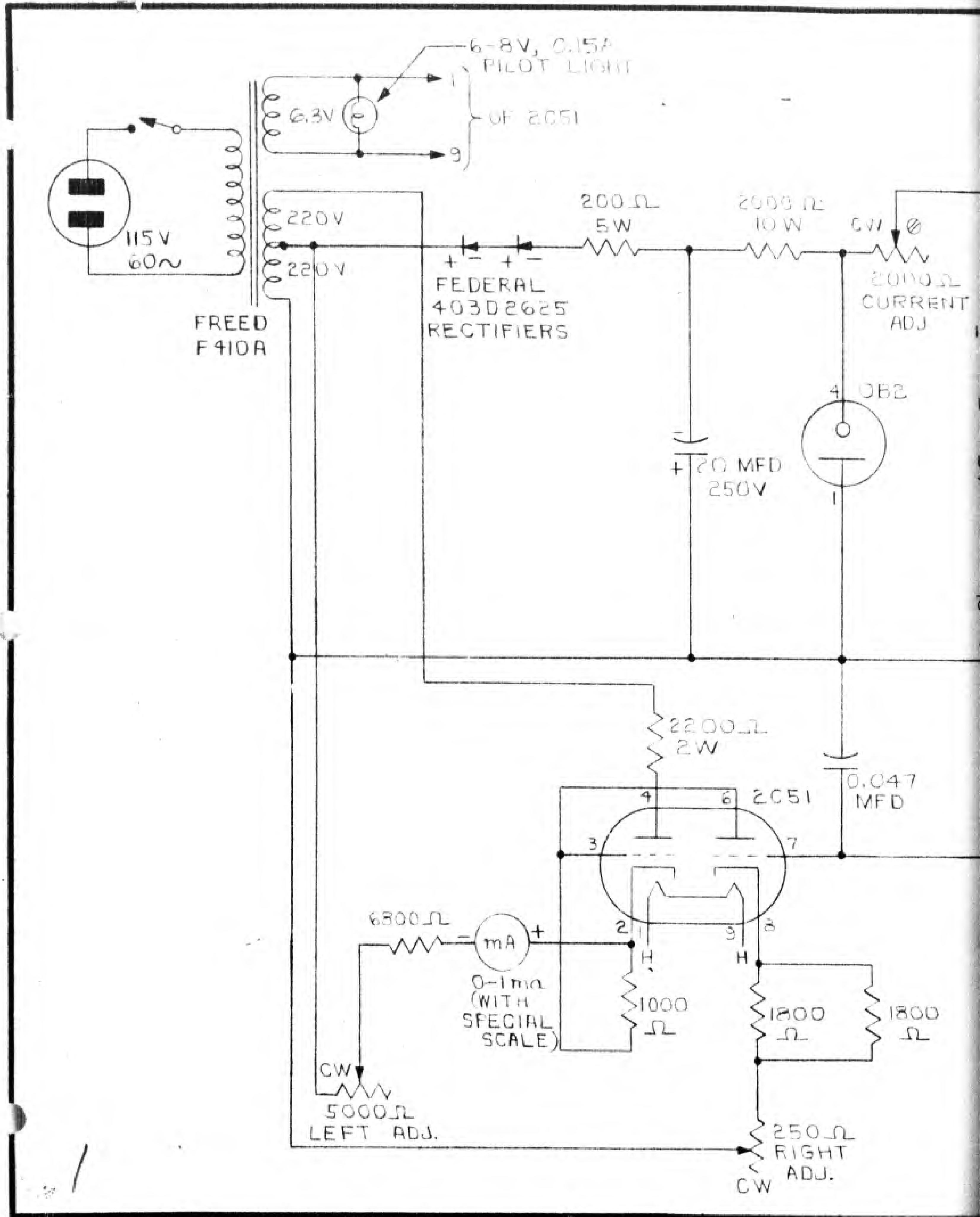
Circuit designs of Whirlwind I indicate that in most applications the back voltage across crystal diodes will be approximately 20 volts.

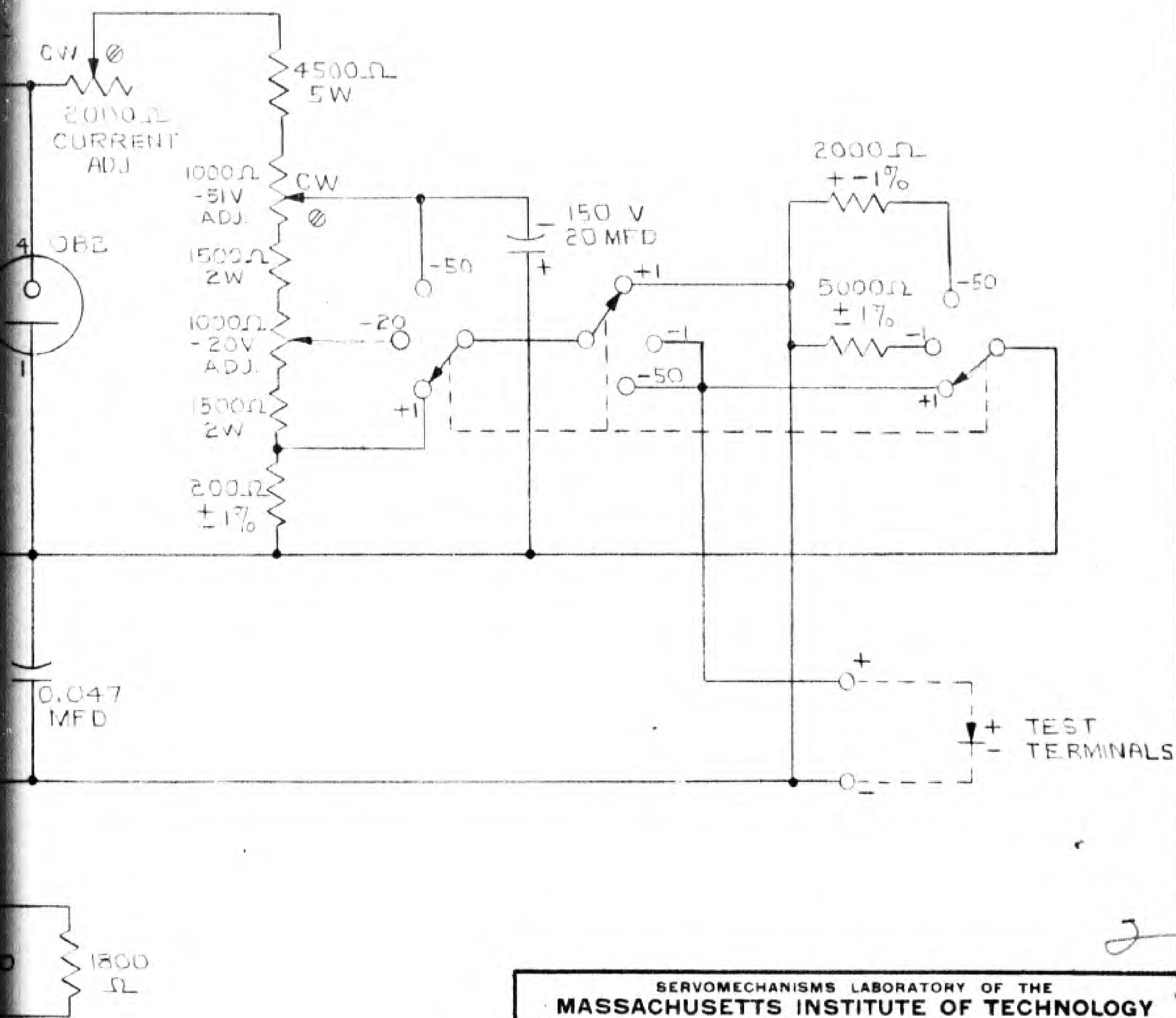
Accordingly, the Model 1 Crystal Tester has been changed so that the resistance of the crystal is measured at plus 1, minus 20 and minus 50 volts.

Drawing B-30465-3 shows the modified circuit.

David J. Crawford
David J. Crawford

DJC:vh

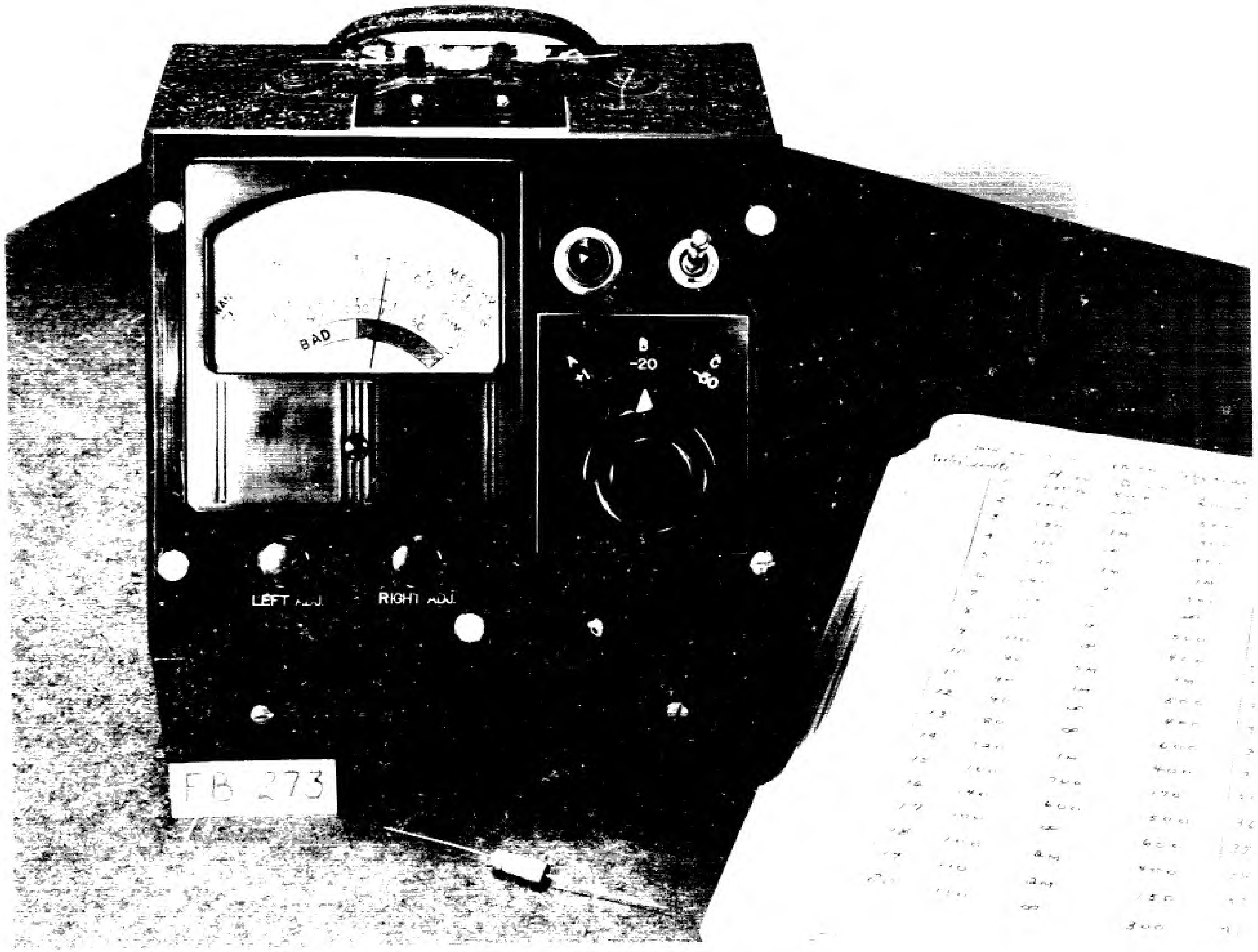

6-8V, 0.15A PILOT LIGHT
6.3V
1
9
OF 2C51
115 V 60~
220 V
220 V
FREED F410A
FEDERAL 403D2625 RECTIFIERS
200 Ω 5 W
2000 Ω 10 W
CW
2000 Ω CURRENT ADJ
4 OB2
1
20 MFD 250V
2200 Ω 2W
0.047 MFD
4
6
2C51
3
7
2
9
8
H
H
6800 Ω
mA
0-1 ma (WITH SPECIAL SCALE)
1000 Ω
1800 Ω
1800 Ω
CW
5000 Ω LEFT ADJ.
250 Ω RIGHT ADJ.
CW



SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO. 6345

SCHEMATIC, CRYSTAL TESTER, MODEL I

SCALE:	DR. D.L.O. 4-11-47		B-30465-3
ENG. DJC	CK. TL 4/11/47	APP.	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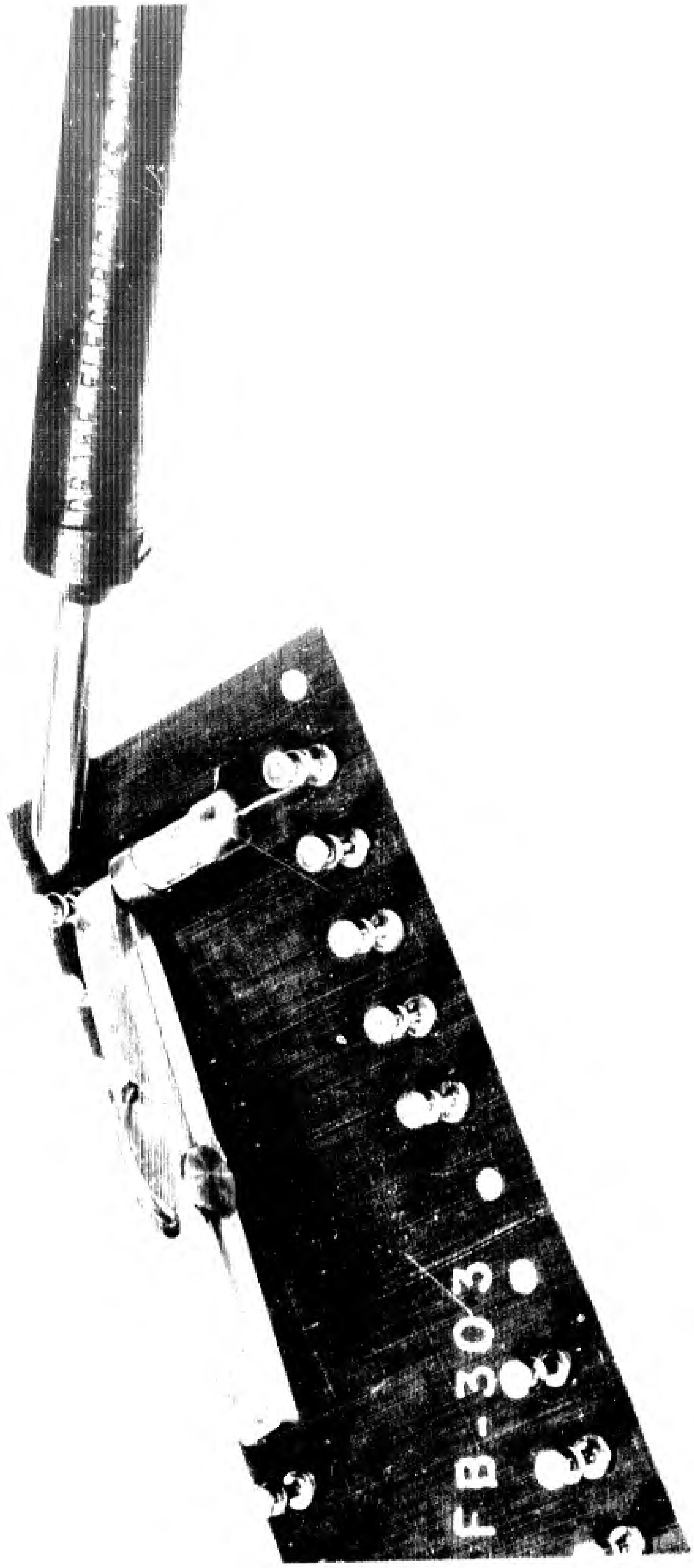
B
-20
C
LEFT ADJ.
RIGHT ADJ.
FB 273


FB-30-3

6345
Memorandum M-110

Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: 1N34 FAILURES AND DETERIORATION

To: N. Rochester, Sylvania, 3 copies
Jay W. Forrester, H. R. Boyd, R. R. Everett,
D. R. Brown, N. H. Taylor

From: H. Fahnestock

Date: October 3, 1947

You and your engineers have reported the failure of a large number of 1N34's in the course of testing our multiplier panels. I have tried to reconcile this with our experience in the past eighteen months with some 2500 crystals. The majority of these have been used by, or under the supervision of, eleven engineers. I have asked all of them approximately the question: "What failures or deterioration of 1N34's have you experienced that could not be explained by exceeding ratings or mistakes in wiring, testing, soldering or dropping?" An analysis of their replies follows:

No. of Engineers Reporting	Experience
8	No unexplained failures
1	3 or 4 unexplained failures
1	2 failures with no effort made to find cause
6	No unexplained failures or deterioration
1	Some cases of resistance deterioration
1	Forward resistance not stabilized in 300 hours

From the above it would appear that your reported recent experience is very different from ours. I would recommend a careful investigation of shop practice and techniques in testing our panels before

concluding that 1N34's are inherently suspect in our applications.

Feel free to circulate this memorandum in your group but not to publish excerpts from it.

Harris Fahnestock
H. Fahnestock

HF:has

Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: STANDARD SYMBOLS FOR OTHER THAN VACUUM TUBE DIODES

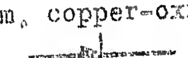
To: All Engineers & Drafting Room

From: C. W. Watt, Jr.

Date: October 14, 1947

A survey of applicable standards and commercial practices made recently by Steve Dodd shows that there is no consistency among various manufacturers as to the marking of their crystal and selenium rectifiers. A standard method of representing them is necessary, and is established below. It will be the responsibility of the engineers to specify the manufacturer of the non-vacuum tube diodes being used, when having schematic circuit diagrams made. The drafting department will then know how to represent and label the diodes on the schematics.

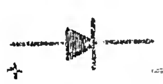
Standard Symbol and Labelling

1. All dry disc and crystal rectifiers (selenium, copper-oxide, germanium, etc.) are to be represented by the symbol  where the arrowhead always represents the direction of conventional current flow (not electron flow).

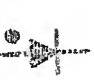
2. Components shall be numbered CR-1, CR-2, etc.

3. Labelling of diodes shall agree with that of the manufacturer, as follows:

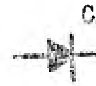
a) A Sylvania crystal diode shall be labelled as follows:


+ −
CR-1 (COMPONENT NO.)
IN-34 (JAN TYPE NO.)
(POLARITY MARKED ON CRYSTAL)

b) A Western Electric crystal diode shall be labelled:

(DOT MARKED ● ON CRYSTAL) 
CR-1 (COMPONENT NO.)
D-172924 (W. E. PART NO.)

c) A Federal Telephone & Radio (FTR) selenium rectifier should be labelled as follows:


CR-1 (COMPONENT NO.)
+ (POLARITY AS MARKED ON RECTIFIER)
F.T.R. #

d) Labelling of any diodes other than the above shall be specified by the engineer when he has a schematic made.

Signed C W Watt, Jr.
C. W. Watt, Jr.

CWW/sp

SERVOMECHANISMS LABORATORY
Massachusetts Institute of Technology
Cambridge, Massachusetts

Date of Report: March 19, 1947

Written by: John J. O'Brien

Subject: Flip-Flop Circuits, Investigation of

Drawings: A-30313, A-30314, A-30315-1, A-30316-1, A-30317, A-30335-1, A-30336-1, A-30337-1, A-30439, D-30438

Photographs: A-30334, A-30335, A-30336

References:

A. "Design and Use of Directly Coupled Pentode Pairs", V. Regner, 6345 File, WW 525.

B. "Decade Counting Circuits", V. Regner, 6345 File, WW 526.

C. 2JJO'B 14-17-Sec. VI

D. 1ABH 37-69-Sec. V

E. 1ABH 77-78-Sec. XII

F. 2JJO'B 46-50-Sec. II and IV

Conclusions: The flip-flop will be a fundamental unit of the computer of Project WHIRLWIND. This report covers an investigation of the circuit with an emphasis on the speed of operation. Circuits of the type desired were found to operate at a frequency of about 10 megacycles. These flip-flop circuits can be used most reliably when set and reset by separate trigger sources as described in II-g.

I. DEFINITION

The flip-flop is a device which has two stable states and can be changed from one to the other by an appropriate trigger impulse. Those described in this report can be looked upon as being two d.c. amplifiers coupled together. The output of one is fed to the input of the other. One of the two tubes will always be conducting and the other, cutoff. The two states are distinguished by which tube is conducting.

II. GENERAL CHARACTERISTICS

a) Bias

Since the control grid of one tube is driven below cutoff, a negative voltage must be supplied. This can be cathode bias as in Drawing No. A-30313. The cathodes could be tied to a positive supply or the ends of the control grid resistors could be brought to a negative one. The latter method, not yet investigated, may have some advantages. With cathode bias, the circuits operate satisfactorily and require only one power supply.

b) Triggering

The circuit can be triggered on any electrode. Drawing No. A-30313 shows cathode triggering. Here either positive or negative triggers can be used. The low cathode impedance is the only disadvantage of this method. When triggered on the control grids as in Drawing No. A-30314, the load on the triggering source is not so large. The crystals tie both control grids to the trigger source through a low impedance and couple the grids together through the high back impedance of one crystal. In this schematic only positive triggers may be used.

Because of the crystals, the charge and discharge times of the input coupling condenser, 0.01 MFD would differ widely if there was no resistor from the junction of the crystals to ground. Inserting this resistor, 8.2K, decreases the discharge time of the condenser by at least a factor of 5, thereby permitting a shorter period between triggers, an increase in prf.

To use negative triggers in this circuit, the crystals must be reversed in polarity and their junction tied through a resistor to the cathode, instead of ground.

c) Delay

The circuits of this report switch on the falling edge of the trigger, so the switching time is increased by an amount equal to the trigger width. To make these circuits act on the leading edge of the trigger requires critical adjustments that are impractical for general use.

d) Trigger Tube

To produce short triggers, especially where one flip-flop drives another, a trigger tube is necessary. Drawing No. A-30315-1 is

the schematic of such a circuit. The plate inductance is tuned by the capacity of the crystal and other stray capacities, to a frequency of the order of 5 megacycles. Through the clipping action of the crystal, the output is one-half cycle of oscillation. The polarity of the output pulse depends upon the polarity of the crystal. The positive trigger results when the tube is cutoff and the negative when the tube is caused to conduct more strongly.

e) Screen Supply

A circuit using pentodes is shown in Drawing No. A-30316-1. The screen voltage is supplied by tieing both screens together and through a resistor to the plate supply. With these connections, the screen voltage is constant because as one tube conducts the other tube is cutoff. The output pulse has a good low frequency response, a flat top.

f) Peaking

Inductance in the plates of the flip-flop tubes has a peaking effect. By them, a capacitive load can be compensated with limits. The following table gives some examples of this effect. The circuit of Drawing No. A-30316-1 was used. The 1K ohm plate resistors of this flip-flop were wire-wound so there was an extra peaking inductance of about 10 μ henries in the plate impedance. Both tubes were loaded by a condenser from the plate to ground as shown in the table below. The measuring equipment added 7 μμf to the capacity load.

Capacity μμf	Inductance μ h	Switching Time μ sec.
0	0	0.056
35	0	.265
35	10	.112
50	0	.33
50	25	.133
75	0	No operation
75	35	0.425

g) Resetting

A resetting trigger can be applied to one control grid, in the flip-flop circuits already shown in Drawings Nos. A-30313, A-30314, and A-30316-1. This trigger assures that the circuit will start in the same position for each cycle of operation. In some sections of the computer, circuits such as Drawing No. A-30327-1 will be used where the set trigger is not applied to each control grid simultaneously. Here the two triggers can be either both positive or both negative. This has been found to be the best method of triggering these circuits. The tolerances on the trigger widths and amplitude are much wider and the flip-flop will switch on the leading edge of the trigger eliminating the delay of the trigger width.

III. LOW-POWER CIRCUIT

Drawing No. A-30314 gives the circuit values for the best low-power flip-flop designed to date. With a type 2051 tube the rise time is slightly faster than with a type 6SF7. The circuit has operated satisfactorily at a trigger rate of one megacycle. The plate supply tolerance is ± 30%. It required a trigger of 10 volts amplitude. The plate dissipation was below 50% of maximum rated value. The output varies with the plate supply from 30 to 75 volts.

IV. HIGH-POWER CIRCUIT

The circuit of Drawing No. A-30316-1 ran with a trigger frequency of 7 megacycles, the limit of available oscillators, but since the rise time was approximately 0.1 microsecond, it should reach 9 megacycles. The plate supply tolerance was ± 25%. The trigger amplitude required was 15 volts. The plate dissipation was below 50% of maximum rated value but the screen dissipation was 65%.

The smaller value of screen resistor given in Drawing No. A-30316-1 can be used when the plate supply is 150 volts or lower. With plate variation the output pulse went from 20 to 40 volts.

V. NON-ECCLES JORDAN CIRCUITS

These flip-flops have not as yet been made to operate as well as the conventional type.

a) Drawing No. A-30326-1

The suppressor grid is the triggered electrode. Only negative triggers can be used. The switching time was 0.6 microseconds. Power Supply tolerance ± 40%. A trigger amplitude of 12 volts was sufficient.

b) Drawing No. A-30325-1

Here, the functions of the suppressor and control grid are interchanged. Either positive or negative triggers may be used. The switching time is approximately 0.75 microseconds. Only a plate supply tolerance of ± 20% was possible. Again, the trigger amplitude was 12 volts.

c) Drawing No. A-30317

The transformers add regeneration to each half of the flip-flop. A complete investigation has not been made of this circuit. However, transformers used similarly in the circuit of Drawing No. A-30316-1 gave a peaking effect and greatly reduced the required trigger amplitude.

d) Circuits

The circuits described by Victor H. Regner in References A and B were tested in the laboratory and found to have an upper frequency limit of 200 kilocycles.

VI. PHOTOGRAPHS

a) Test Circuit

Drawing No. D-30438 shows the test circuit used to obtain photographs of some waveforms of flip-flops when triggered at a high prf of 7 megacycles. A frequency divider was necessary to produce a pulse at about 5 kilocycles prf in synchronism with the 7 megacycle pulses to trigger the Model 5 Synchroscope sweep. Since the frequency divider contained as components the two types of flip-flops to be tested, it seemed best to examine their waveforms while under the operating conditions of the frequency divider. A cathode follower probe, Drawing No. A-30439, was used to bring the signal from various points in the frequency divider to the vertical plates of the Model 5 Synchroscope.

The synchroscope had a vertical calibration of 52 volts per large division, and the cathode follower probe an attenuation of 0.6. So, for an interpretation of the photographs, the vertical calibration can be considered as 86.5 volts per large division.

The input capacity of the cathode follower probe was 15 μμf. This was the greatest capacity load on any of the photographed points.

The following table gives the number of traces on the synchroscope during each exposure.

Photograph No.	No. of traces/exposure
A-30334	850
A-30335	120
A-30336	
Fl3-1, -2, -3	850
Fl3-4, -6	106

b) Drawing No. A-30335

Fl3-10 is the waveform of the output of a trigger tube, Drawing No. A-30315-1, taken at point A in Drawing No. D-30438. Here the trigger fed to the flip-flop is 0.1 μ sec. long.

Fl3-15 shows the waveform at point C in Drawing D-30438 of the same type circuit, using a triode. The output trigger is 0.2 μ sec. long.

c) Drawing No. A-30336

Fl3-1, -2, -3, give the waveforms at point B in Drawing No. D-30438, of the high-speed flip-flop, Drawing No. A-30316-1, when triggered at a 7 megacycle prf. Because of the probe, this flip-flop had a wiring capacity load of about 4 μμf on one plate and about 20 μμf on the plate that was photographed.

Fl3-4 and -6 give better detail of the rise and fall times at the same point.

d) Drawing No. A-30334

Fl3-7, taken at point D in Drawing No. D-30438 is the waveform of the low-speed flip-flop of Drawing No. A-30314. Again, it had an unbalanced capacity load. The circuit was being triggered at about one megacycle prf.

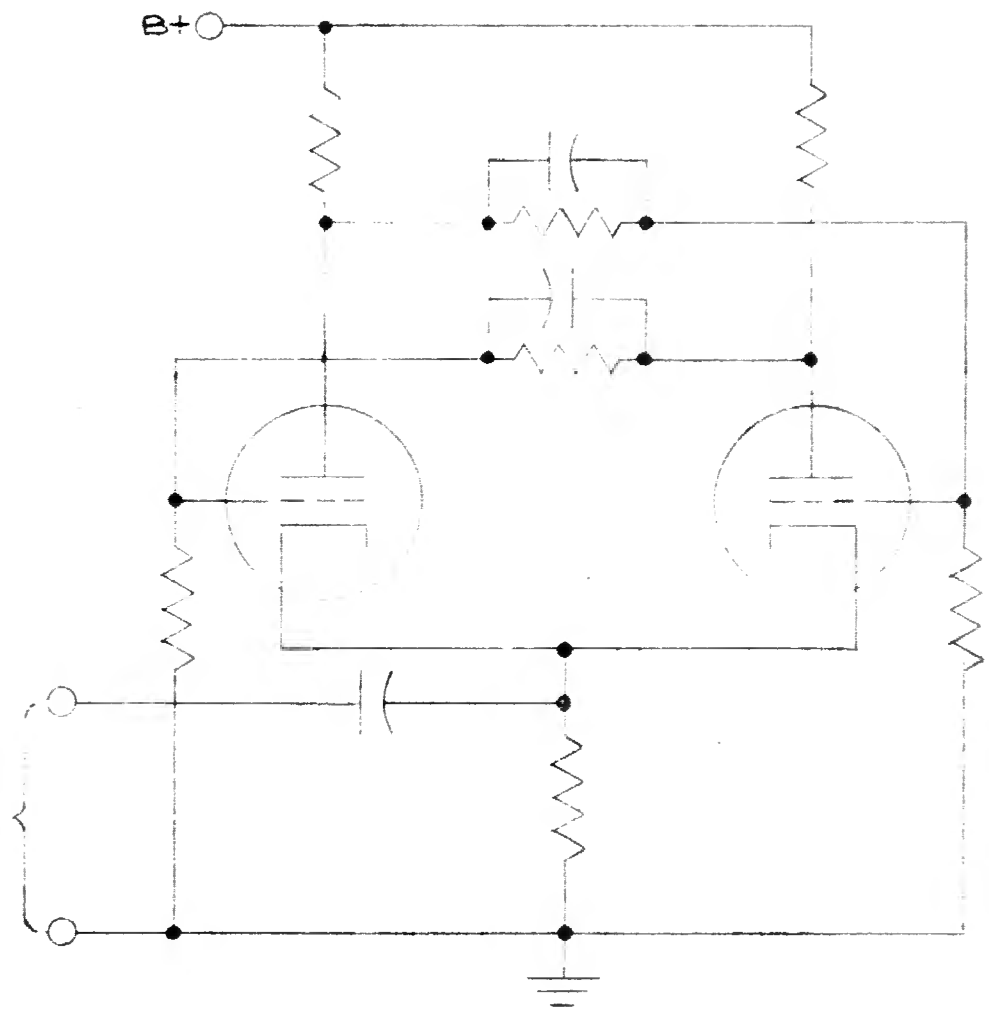
Fl3-8 and -9 give the detail of the rise and fall times taken at the same point.

Engineer: J. J. O'Brien

Approved: JF

JJO'B:has

A-30313

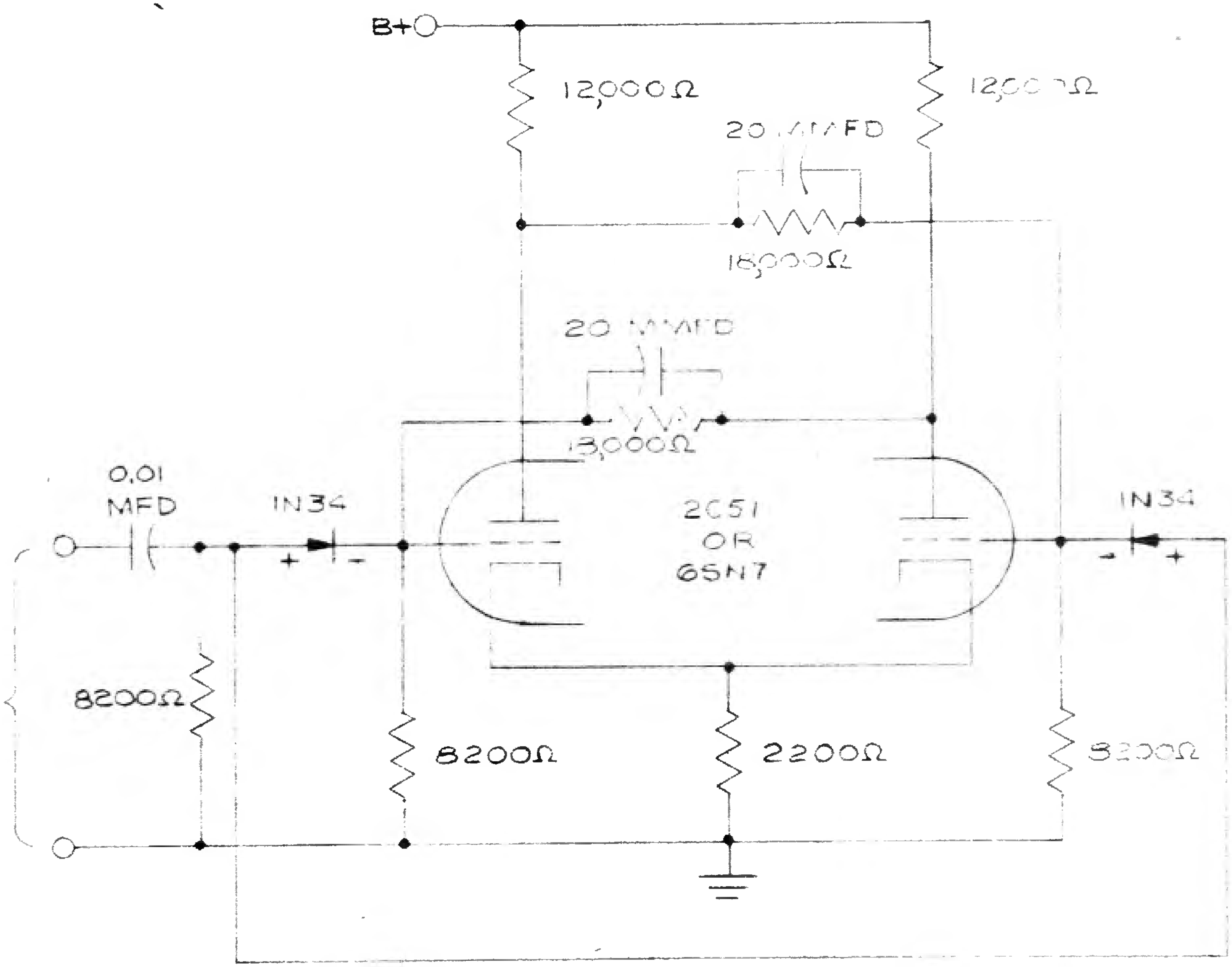


CATHODE-TRIGGERED FLIP-FLOP

USED IN 6345 REPORT R-113

MASSACHUSETTS INSTITUTE OF TECHNOLOGY SERVOMECHANISMS LABORATORY		
D. I. C. NO. 6345	DR. HHS 1/27/47	CK. TL 1/27/47
J.J.O'B	APP.	A-30313

A-30314

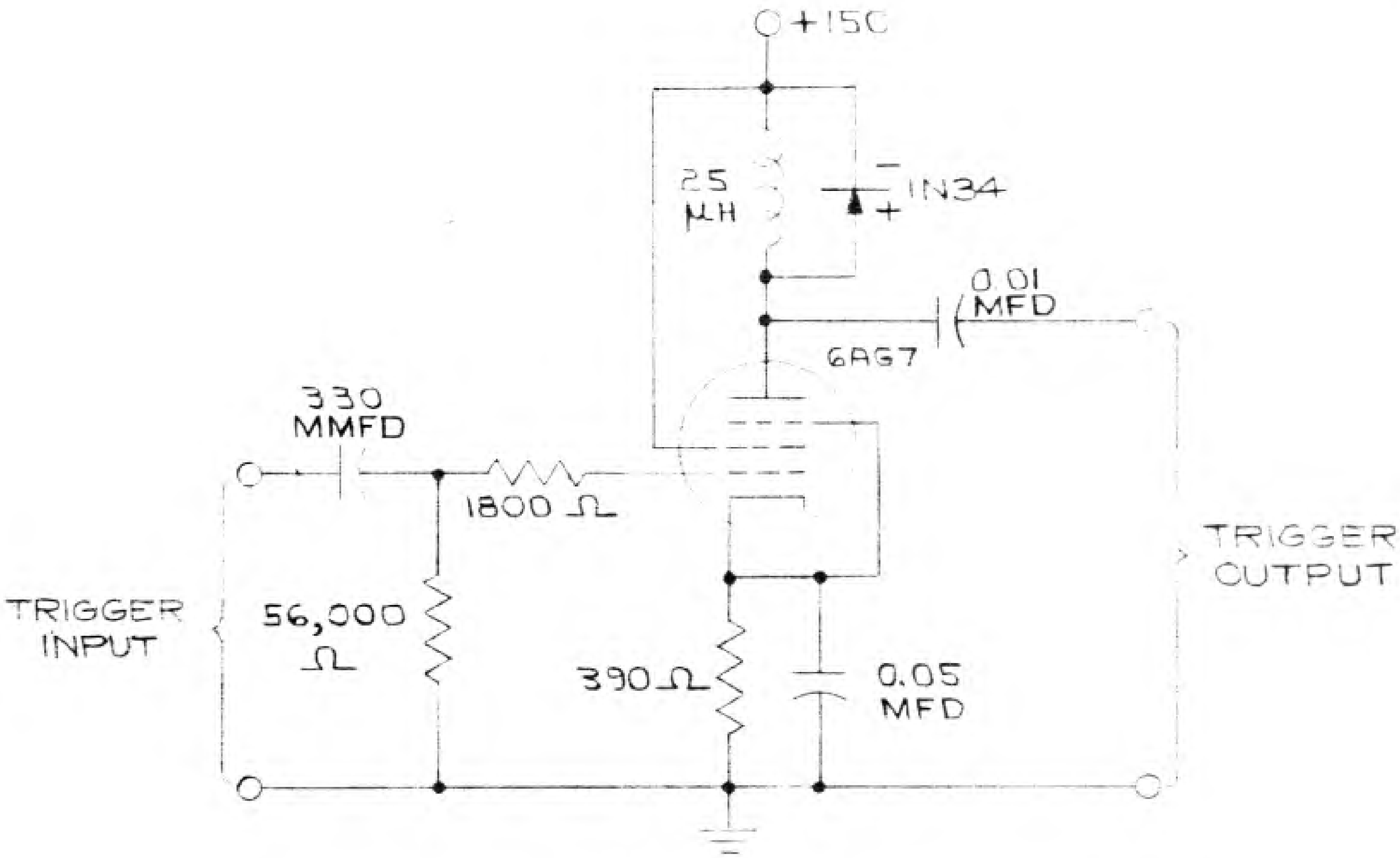


LOW-SPEED FLIP-FLOP

USED IN 6345 REPORT R-113

MASSACHUSETTS INSTITUTE OF TECHNOLOGY SERVOMECHANISMS LABORATORY		
6345	HHG 1/27/47	TL 1/27/47
J.J.O'B.	A-30314	

A-30315-1



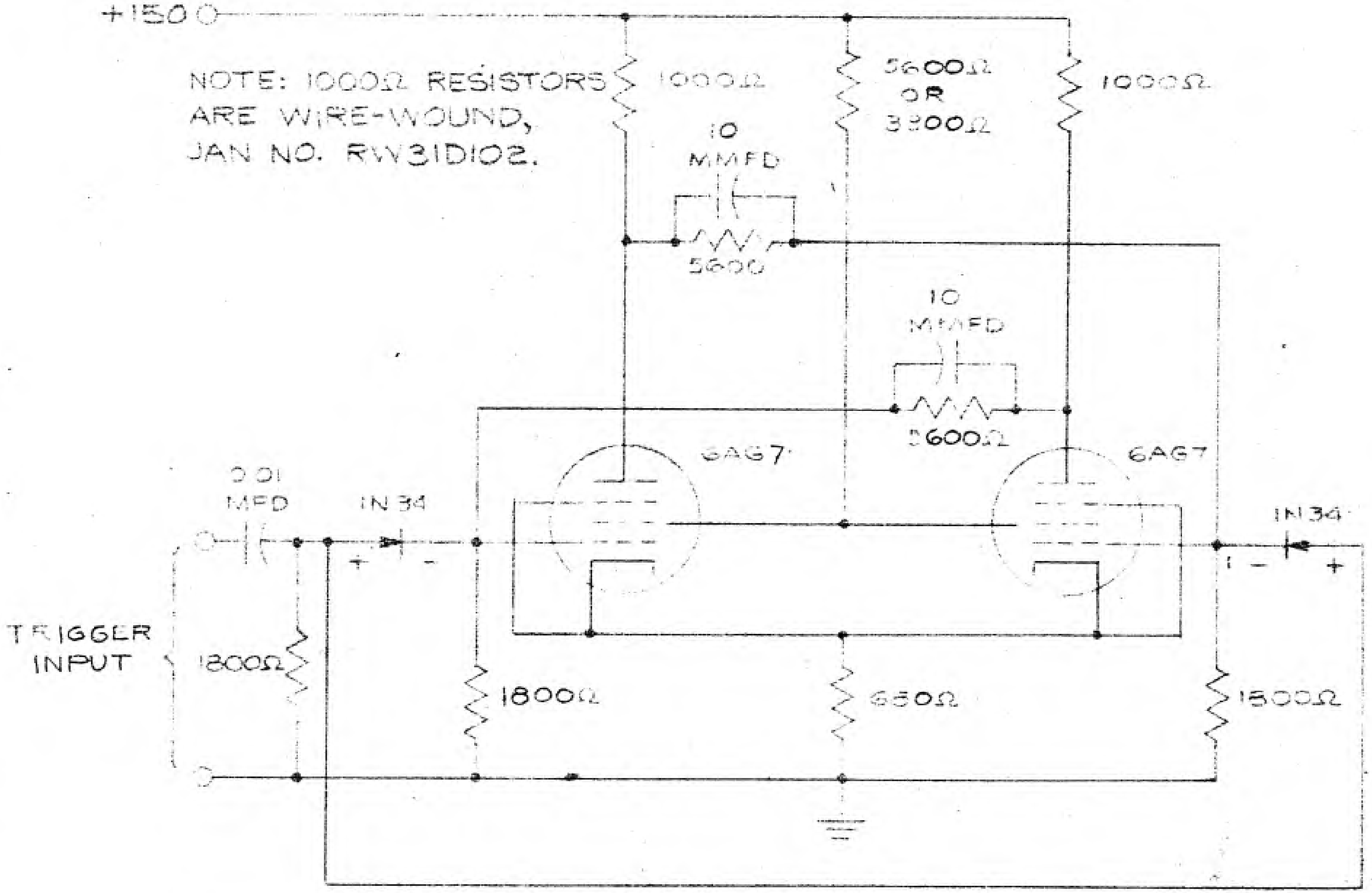
TRIGGER TUBE

USED IN 6345 REPORT R-113

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY

D. I. C. NO. 6345	DR. HHS 1/27/47	CK TL 1/27/47
ENG. J.J.O.B.	APP.	A-30315-1

A-30316-1



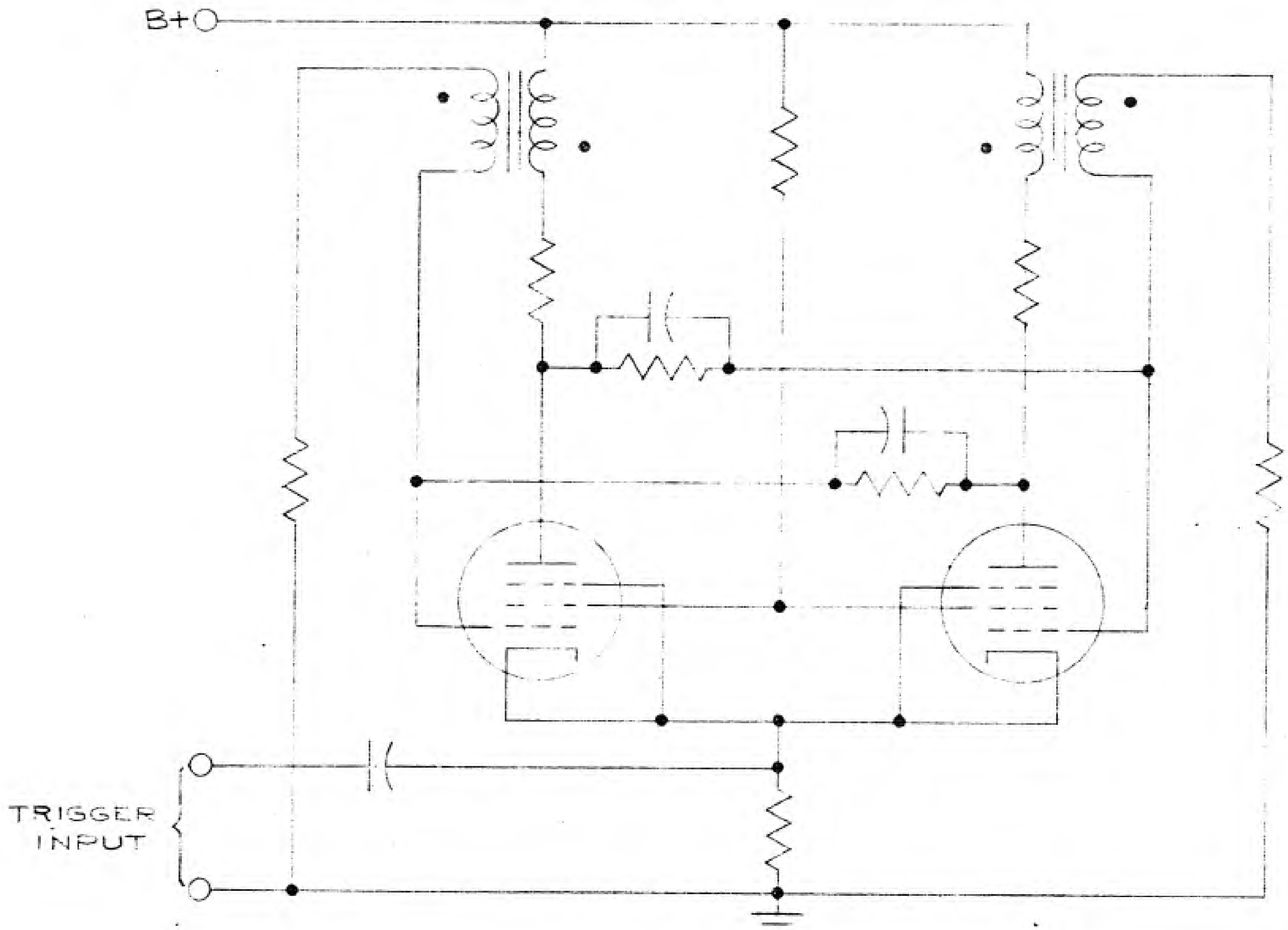
HIGH-SPEED FLIP-FLOP

USED IN 6345 REPORT R-113

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY

D. L. C. NO. 6345	DR. HHS 1/27/47	CK. TL 1/27/47
DRG. J.J. 015	APP.	A-30316-1

A-30317



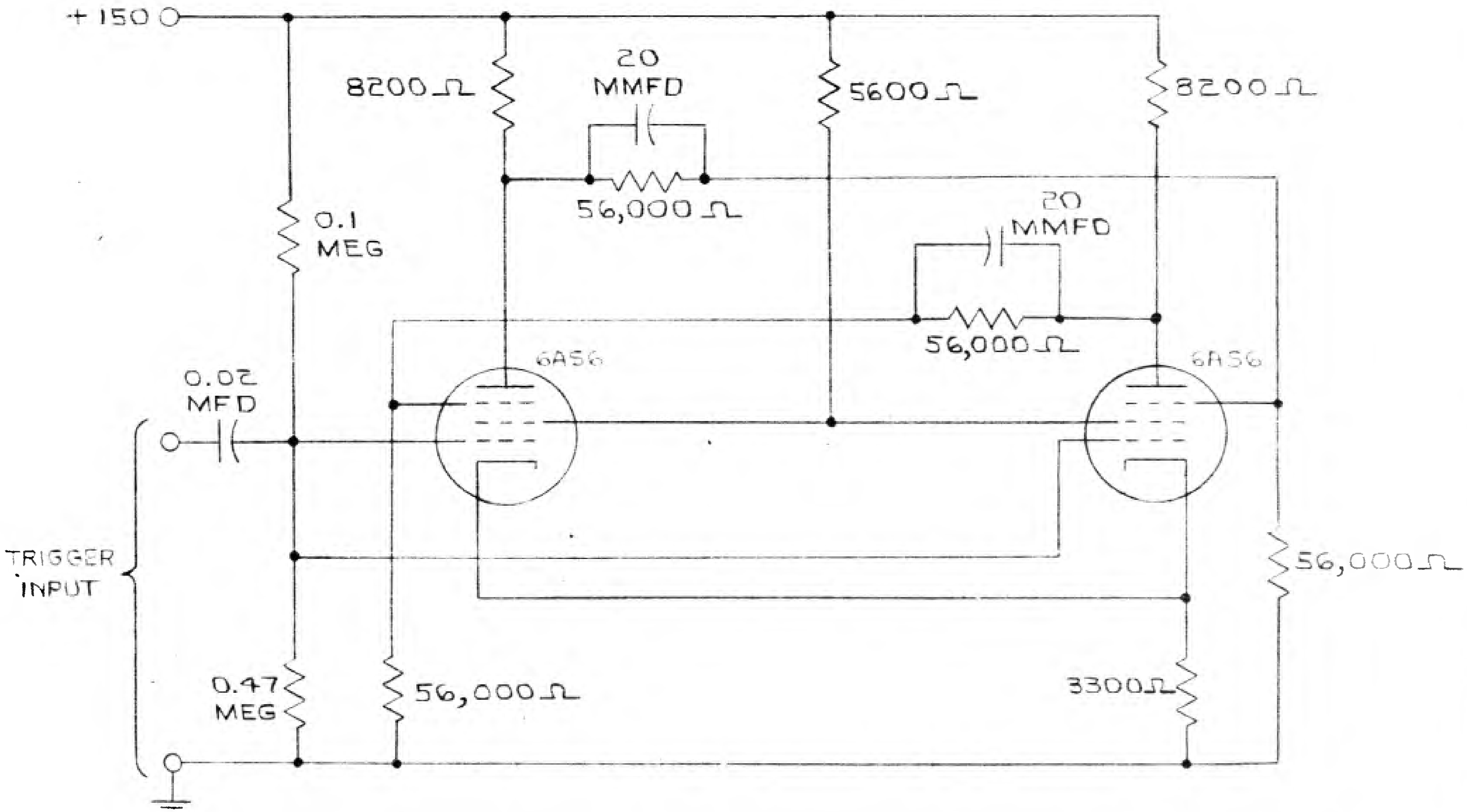
HIGH-SPEED FLIP-FLOP
WITH THE ADDITION OF REGENERATION

USED IN 6345 REPORT R-113

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY

D.I.C. NO. 6345	DR. HHS 1/27/47	CK TL 1/27/47
ENG. J.J. [illegible]	APP.	A-30317

A-30325-1

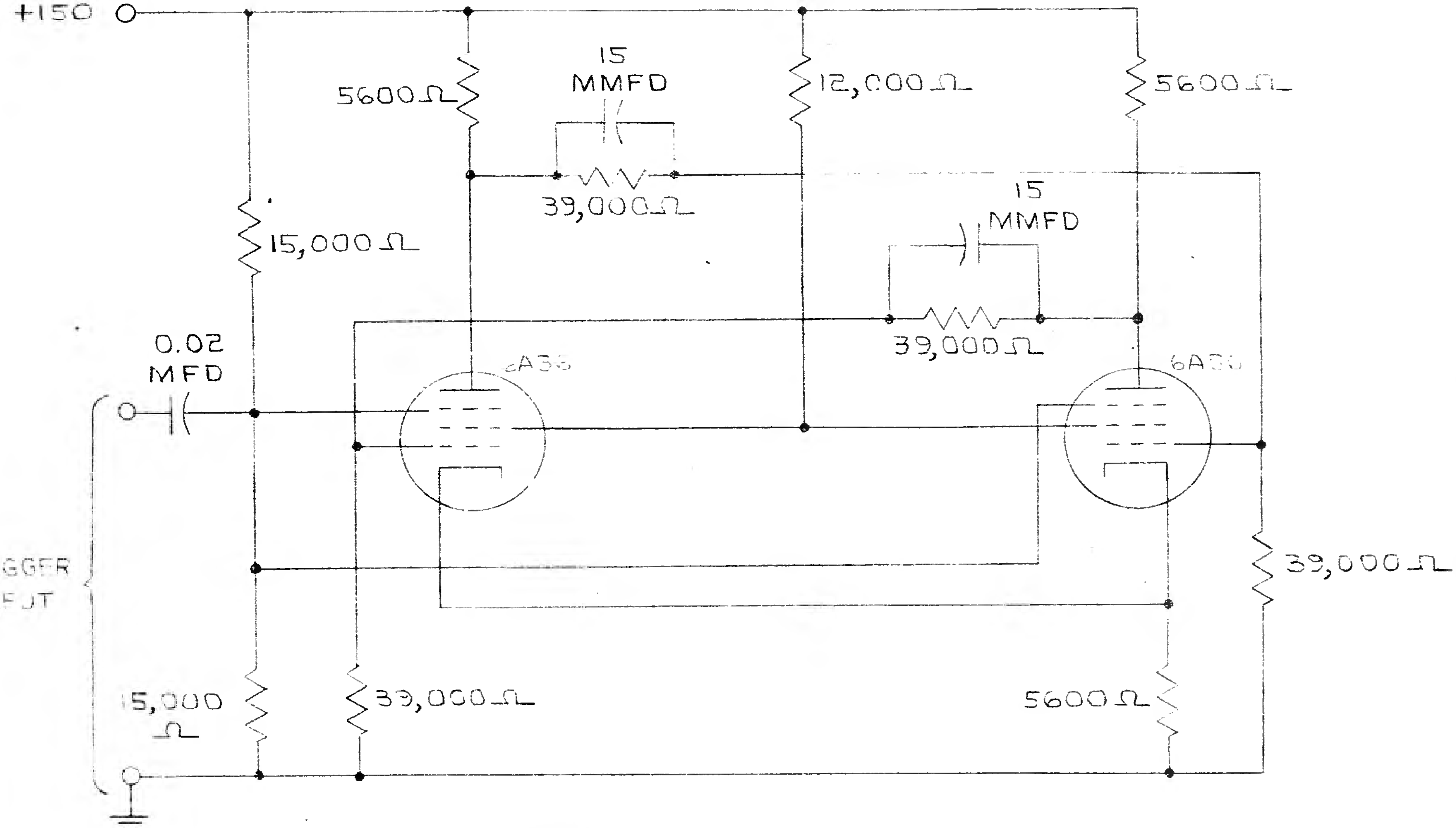


UNCONVENTIONAL FLIP-FLOP CIRCUIT NO. 1

USED IN 6345 REPORT R-113

MASSACHUSETTS INSTITUTE OF TECHNOLOGY SERVOMECHANISMS LABORATORY		
S.L.C. NO. 6345	DR D.L.O. 2-10-47	CK TL 2/10/47
ENG J.T.O.B	APP.	A-30325-1

A-30336-1

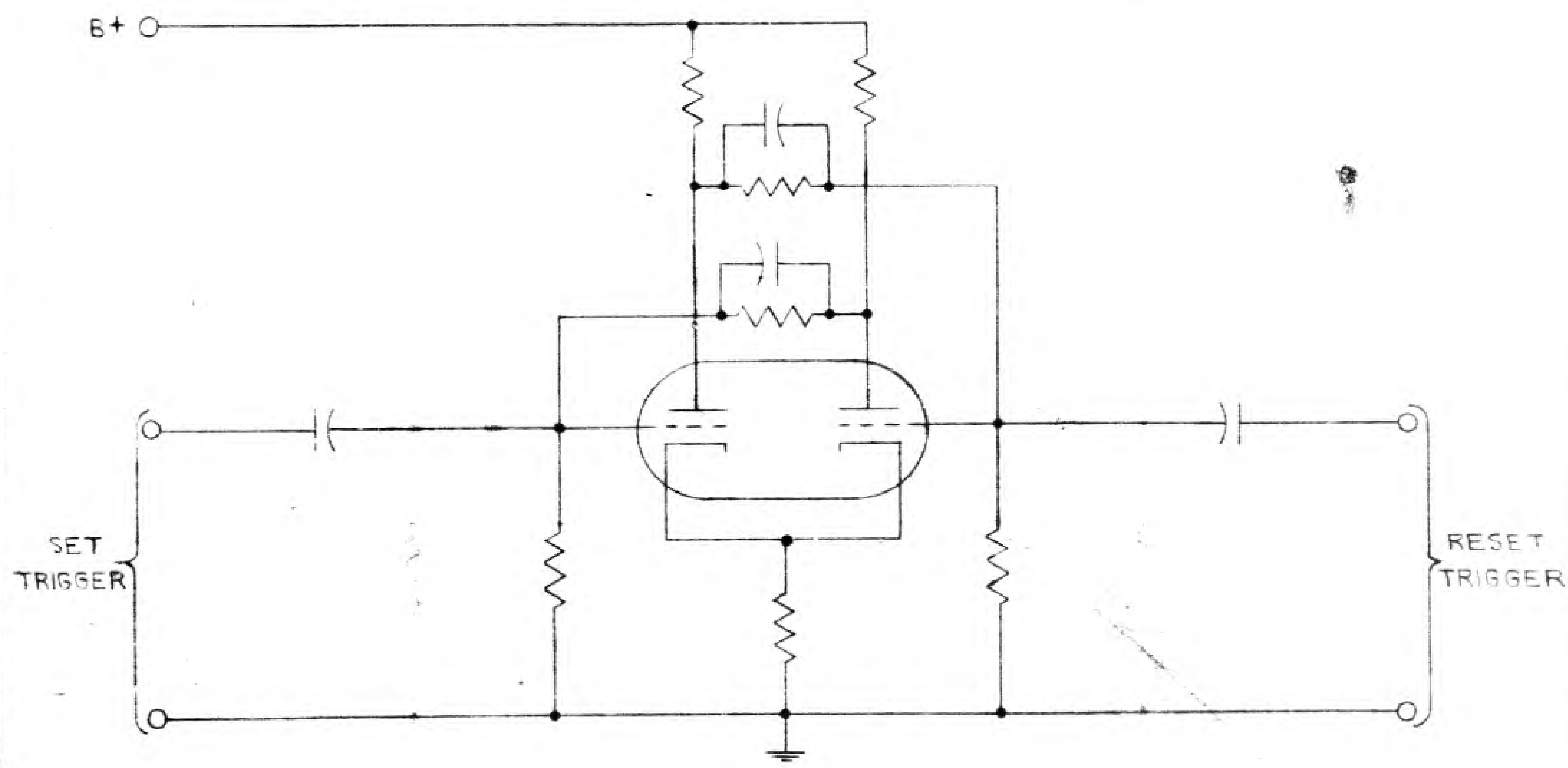


UNCONVENTIONAL FLIP-FLOP CIRCUIT NO. 2

MASSACHUSETTS INSTITUTE OF TECHNOLOGY SERVOMECHANISMS LABORATORY		
D.I.C. NO. 6345	DR D.L.O. 2-10-47	CK
ENG J.J.O.B.	APP.	A-30336-1

USED IN 6345 REPORT R-13

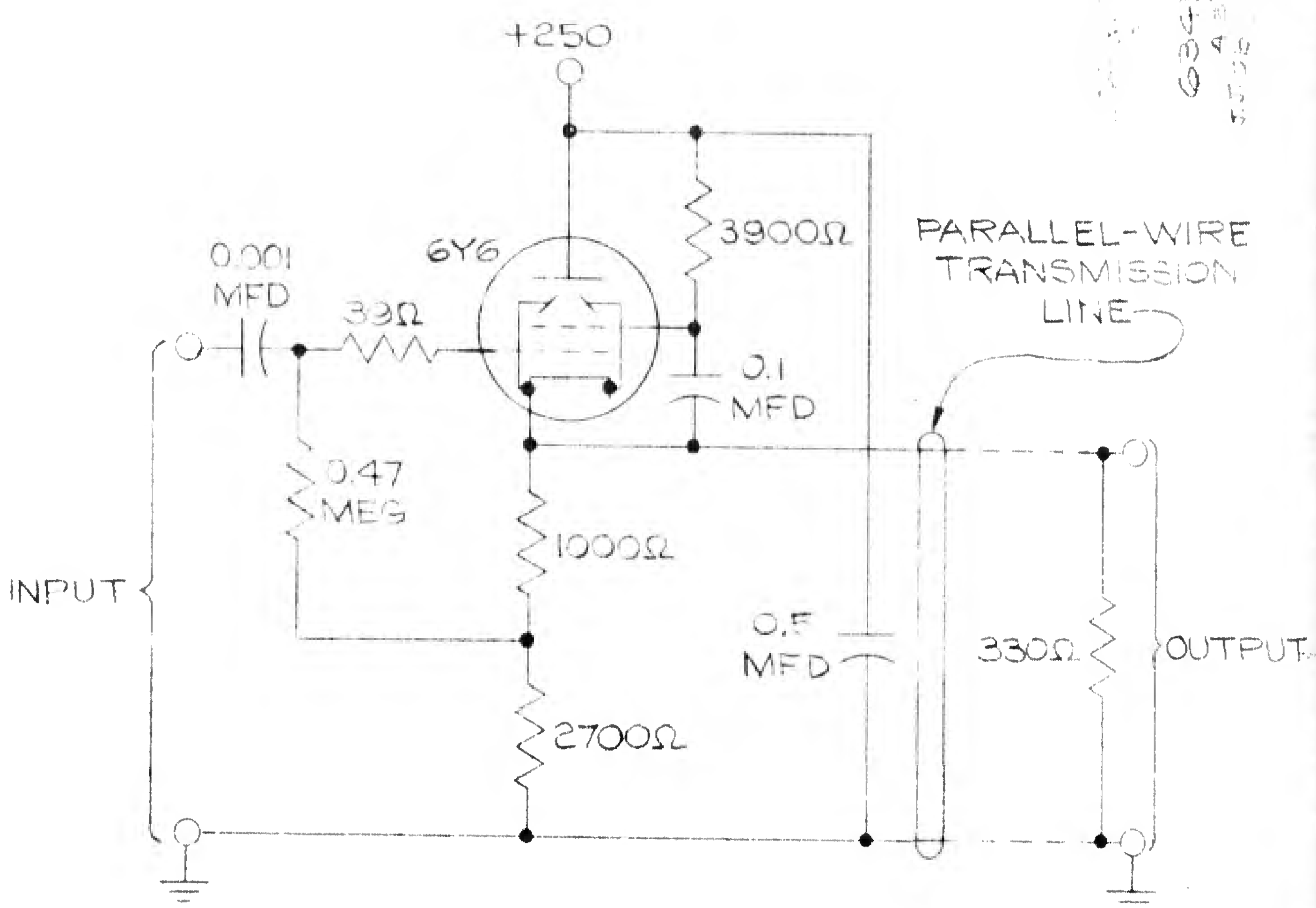
A-30327-1



FLIP--FLOP RESETTING METHOD

USED IN 6345 REPORT R-113

MASSACHUSETTS INSTITUTE OF TECHNOLOGY SERVOMECHANISMS LABORATORY		
D.I.C. NO. 6345	DR DLO 2/12/47	CK TL 2/12/47
ENG J.T.O.B.	APP.	A-30327-1

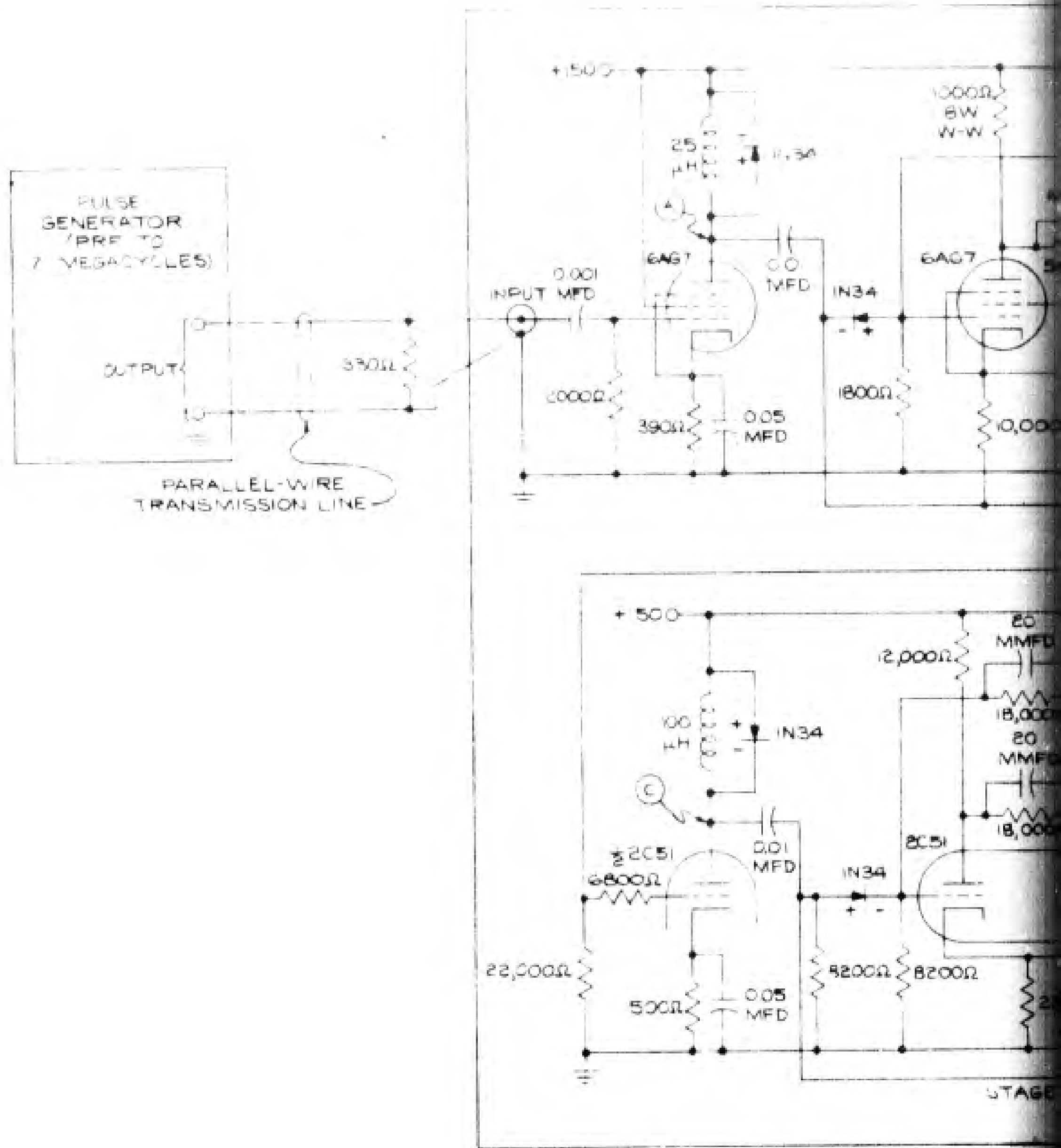


CATHODE FOLLOWER PROBE CIRCUIT SCHEMATIC

4-30433

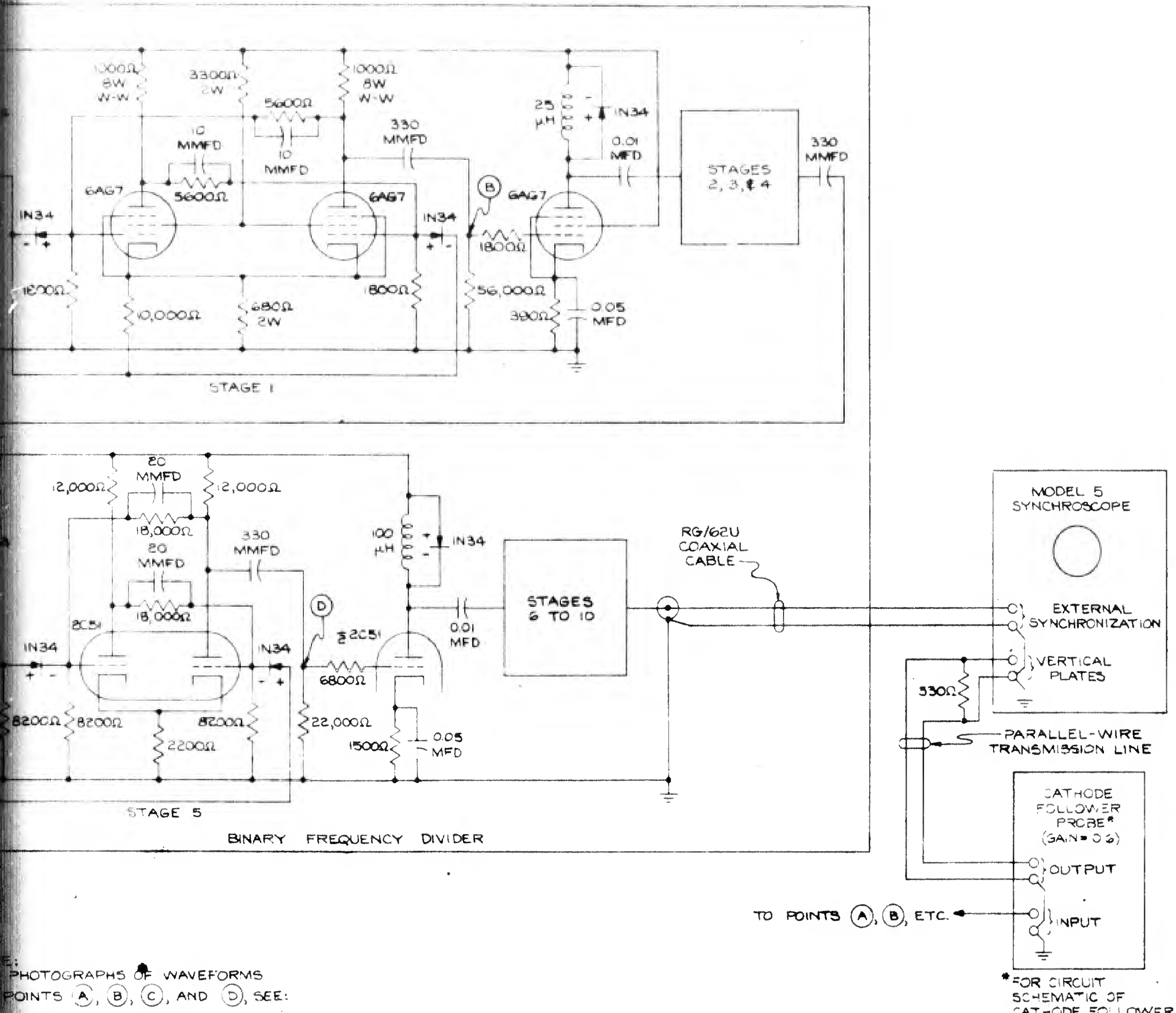
USED IN 6345 REPORT R-113

D 30438	TOLERANCES NOT OTHERWISE SPECIFIED: DECIMAL ± .005 FRACTIONAL ± 1/64
WO	



NOTE:
FOR PHOTOGRAPHS OF W
AT POINTS (A), (B), (C),

POINT	DRAWING
(A)	A-30335,
(B)	A-30336
(C)	A-30335,
(D)	A-30334



*FOR CIRCUIT SCHEMATIC OF CATHODE FOLLOWER PROBE, SEE DRAWING A-30439.

E:
PHOTOGRAPHS OF WAVEFORMS
POINTS A, B, C, AND D, SEE:

POINT	DRAWING NO.
A	A-30335, F.3-10
B	A-30336
C	A-30335, F13-15
D	A-30334

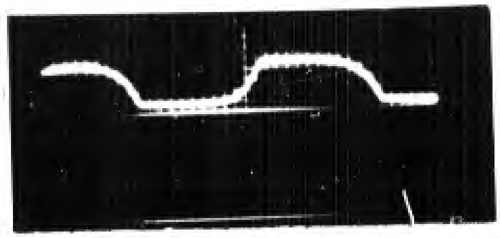
USED N 6345 REPORT R-113

SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO. 6345

FLIP-FLOP TEST CIRCUIT

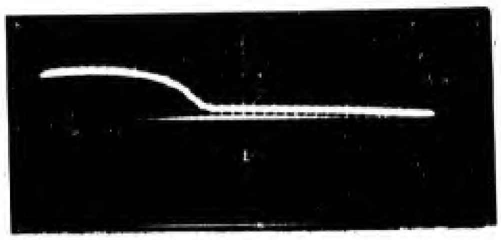
DR. T. Leary 3/1/47
TR. 4/3/47 J.J.O.B.

D-30438



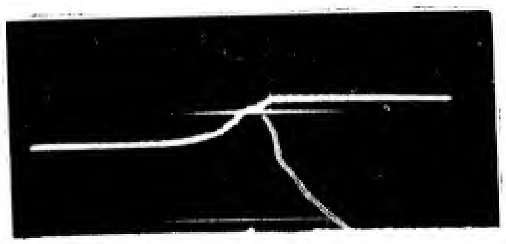
F 13-7

SWEEP SPEED : 1.01 μSEC PER LARGE DIVISION



F 13-8

SWEEP SPEED : 0.54 μSEC PER LARGE DIVISION



F 13-9

SWEEP SPEED: 0.54 μSEC PER LARGE DIVISION

VERTICAL CALIBRATION
52 VOLTS / LARGE DIVISION

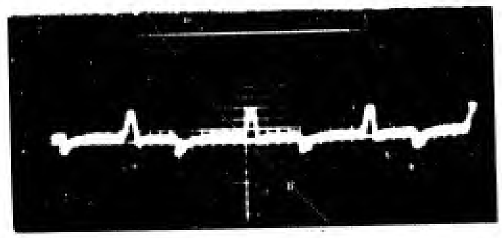
PLATE VOLTAGE WAVEFORMS OF
FLIP-FLOP CIRCUIT, DRAWING A-30314

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY
D.I.C. NO. 6345 BY F.B. 2/21/47 CK TL 2/21/47
ENG. T.J.O'T3 APP. A-30334-1

USED IN 6345 REPORT R-113

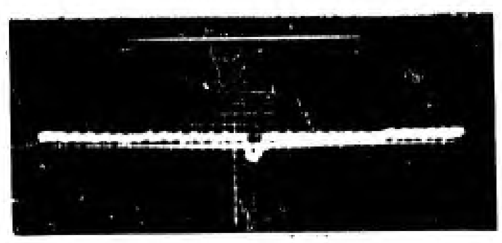
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY

D.I.C. NO. 6345 | DR. F.B. 2/21/47 | CK T.L. 2/21/47
ENG. J.T.G. | APP. | A-30335-1



F 13-10

SWEEP SPEED: 1.01 μSEC PER LARGE DIVISION



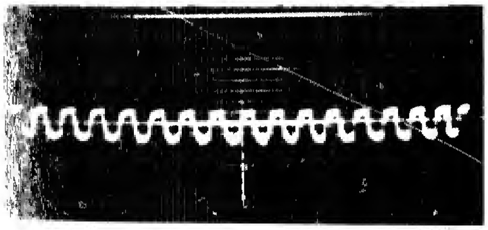
F 13-15

SWEEP SPEED: 1.01 μSEC PER LARGE DIVISION

VERTICAL CALIBRATION
52 VOLTS / LARGE DIVISION

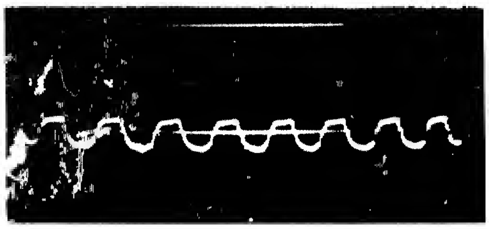
PLATE VOLTAGE WAVEFORMS OF
TRIGGER TUBE, DRAWING A-30315

USED IN 6345 REPORT R-113



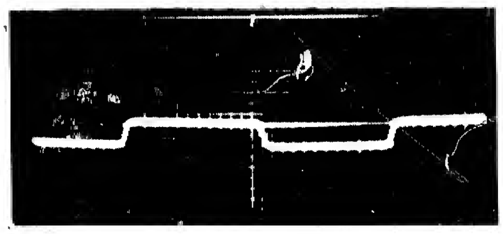
F13-1

SWEEP SPEED: 1.01 μSEC PER LARGE DIVISION
TRIGGERED AT 7 MEGACYCLE RATE



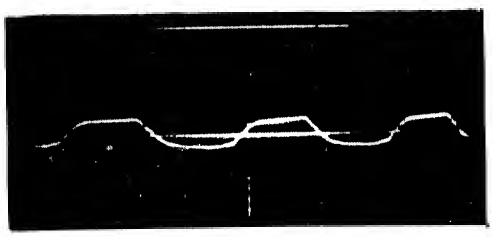
F13-2

SWEEP SPEED: 0.54 μSEC PER LARGE DIVISION
TRIGGERED AT 7 MEGACYCLE RATE



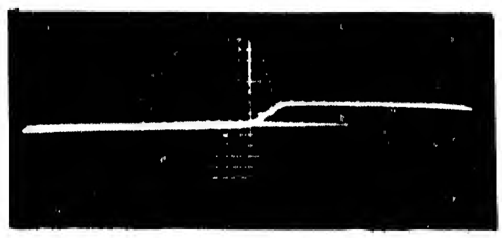
F13-4

SWEEP SPEED: 1.01 μSEC PER LARGE DIVISION
TRIGGERED AT 0.875 MEGACYCLE RATE



F13-3

SWEEP SPEED: 0.2 μSEC PER LARGE DIVISION
TRIGGERED AT 7 MEGACYCLE RATE



F13-6

SWEEP SPEED: 0.2 μSEC PER LARGE DIVISION
TRIGGERED AT 0.875 MEGACYCLE RATE

VERTICAL CALIBRATION
52 VOLTS / LARGE DIVISION

PLATE VOLTAGE WAVEFORMS OF
FLIP-FLOP CIRCUIT, DRAWING A-30316

USED IN 6345 REPORT R-113

ENGINEERING NOTES NO. E-48

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

TO:	6345 Engineers	6345
FROM:	John J. O'Brien	Page 1 of 3 pages
SUBJECT:	Flip-flop Circuit	Drawing: SB-39272-2
REFERENCE:	Report R-113	
DATE:	July 2, 1947	

1. Introduction

This Engineering Note is a description of a flip-flop circuit, Sketch No. SB-39272-2, designed for use in the accumulator.

2. Line Terminations

Short lengths of RG-65/U, 1000-ohm cable, used as delay elements, are difficult to terminate exactly. Therefore, to cut down noise and reflected triggers, both ends of these cables should be terminated in an impedance as close to the characteristic impedance as is possible.

Three RG-65/U lines will bring triggers into this circuit. The complementing trigger cable is terminated in an impedance close to 1000 ohms when the input impedance of the cathode follower is shunted by 1500 ohms.

In each control grid of the flip-flop signals from an RG-65/U and from a 100 ohm, RG-62/U, must be mixed and both lines terminated correctly. The mixing and terminating circuit is shown in the dotted block marked 2.

3. Trigger Characteristics

A. The complementing positive trigger is fed through the cathode follower to the cathode of the flip-flop. The crystal shunting the 0.1 megohm resistor is to clamp and prevent the increase of bias at high duty cycles. Trigger characteristics are given in the following table.

Trigger Width	Trigger PRF		Minimum Trigger Amplitude		
μ sec.			Volts		
		Plate Supply =	100	150	200
0.0625	500 cycles		7	9.5	12.
0.4	500 cycles		5.4	6.7	7.9
0.05	4 megacycles		6.2	8.8	9.6

The maximum trigger amplitude in all the above types of triggers is over 50 volts.

B. The set and reset triggers fed to the control grid circuits have a minimum amplitude of about 1.5 volts at a PRF of 500 cycles, and a plate supply of 150 volts. The width may vary from 0.1 to 0.7 μ sec. The maximum trigger amplitude is over 50 volts.

C. A 100 microhenry choke is placed in each plate lead principally to lower the minimum amplitude of trigger required.

4. D. C. Voltages

The following voltages were measured with a voltohmyst, SN 2652.

Plate Supply = 150 volts.

A. Flip-flop Voltages

	V_1 Volts		V_2 Volts	
Plate to ground	84	121	84	121
Grid to ground	35	27	37	26
Cathode to ground	35		36.5	
E_p	50	88	48	89
E_{g_1}	-0.2	-13	+0.2	-9.4
E_{g_2}	90		85	
$^{*}E_{g_1}$	0	-11.6	0	-11

* One grid shorted to the cathode.

B. Trigger Tube Voltages

	Volts
Cathode to ground	33
E_p	117
E_{g_1}	-4.2
E_{g_2}	89

5. Stability

Some of the previous flip-flop circuits had an instability which was increased by component tolerances. Occasionally after a week or so of satisfactory operation the circuit would multivibrate. This instability was shown also in flip-flops which could not be set and reset while they were being complemented every ten microseconds.

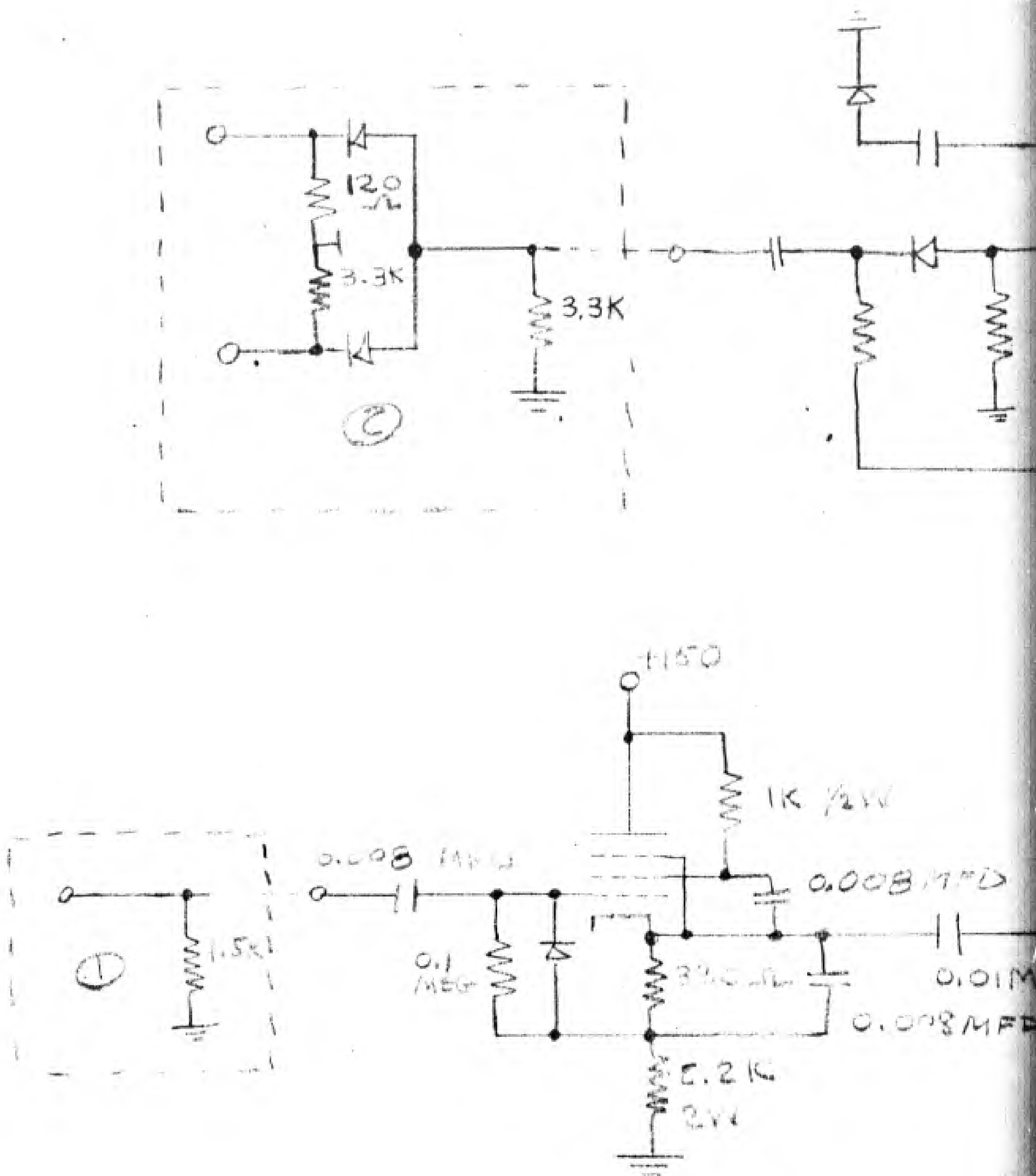
As an attempt to overcome this difficulty, first, the control grid swing was increased to insure sufficient negative voltage on the grid of the off tube. Secondly, the cathode resistor is condenser coupled to the cathode follower, so that the conducting tube acts like an amplifier with regeneration. This tends to keep the grid voltage of the conducting tube at zero.

With the screen at 100 volts, a 6AG7 tube is cutoff at about -6.5 volts. The design should give a grid swing from 0 to 12 volts. This is shown in Section 4A, where the swing is 0 to 11. volts, when the grid of the conducting tube is held at 0 volts.

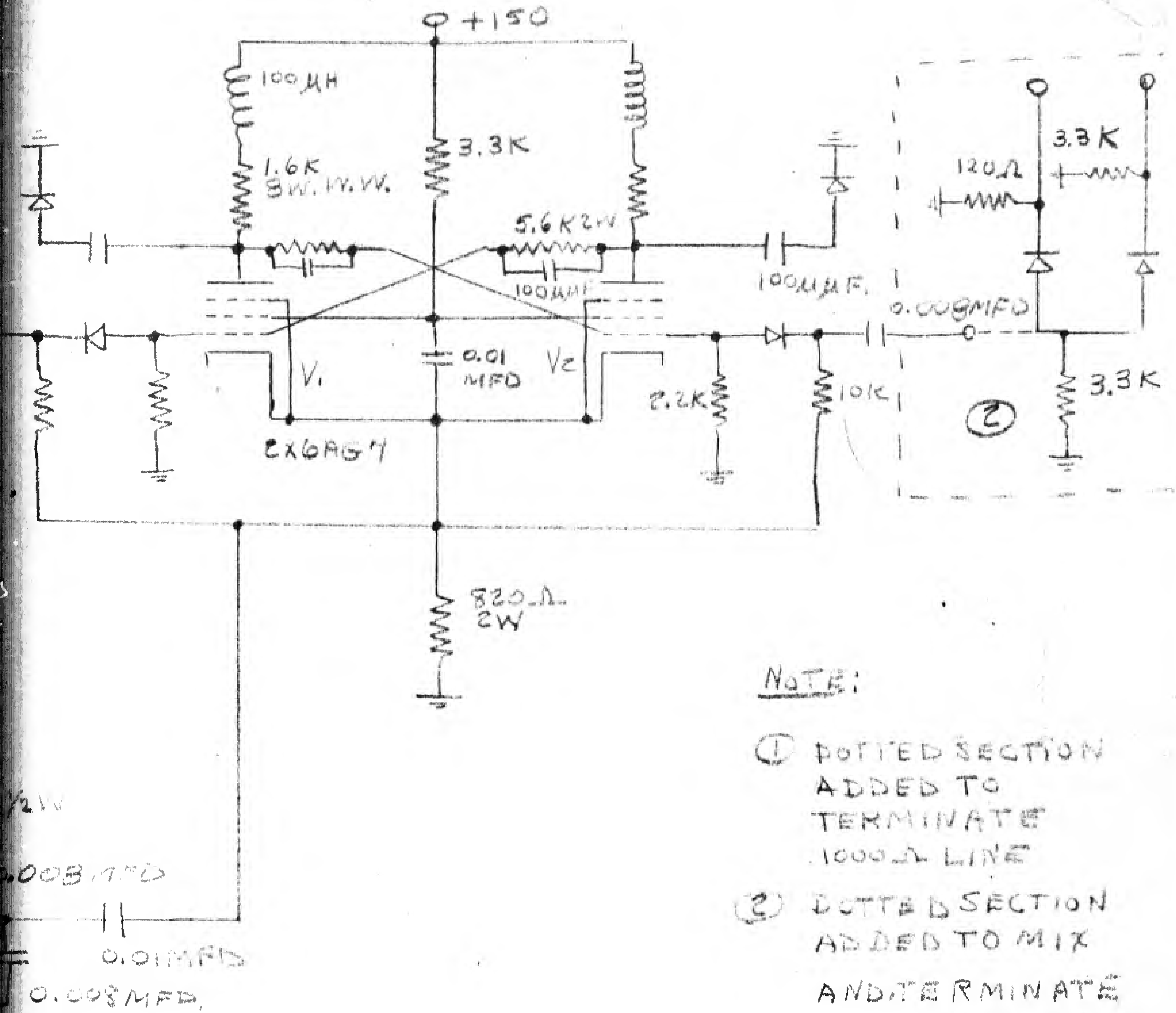
An indication of the effect of circuit tolerances is given in Section 3A. Here the complementing trigger was measured with the plate supply at 100, 150, and 200 volts.

John J. O'Brien
John J. O'Brien

JJO'B:haa



FLIP FLOP UNIT N



NOTE:

(1) DOTTED SECTION ADDED TO TERMINATE 1000Ω LINE

(2) DOTTED SECTION ADDED TO MIX AND TERMINATE 1000Ω AND 100Ω LINES

P UNIT No. 2

2

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY

6345	JJOB 6/23/47	
JJOB	SB-39272-2	

ENGINEERING NOTES E-56

SERVOMECHANISMS LABORATORY
Massachusetts Institute of Technology
Cambridge, Massachusetts

To: 6345 Engineers

From: Louis D. Wilson

Subject: Notes on the Development of Flip-flop for Project Whirlwind

Date: August 8, 1947

Numerous flip-flops have been built and tested. Of these only three appear to be of value for the work of this project. These are: first, a triode flip-flop using the 2C51 twin triode; a second triode flip-flop using the 7F8 twin triode and a flip-flop using a pair of 6AG7 pentodes. The application of the two triode flip-flops is rather limited because of the long time required to switch them from one state to the other. For this reason most of the project work has been on the 6AG7 pentode flip-flop. The first requirement which need be satisfied by this flip-flop is high operating speed. This requirement was fulfilled satisfactorily by an early model as typified by Dwg. A-30316-1. This model would operate quite satisfactorily and switch in less than 1/10 microsecond. However, there were numerous other difficulties; in particular, the flip-flop was very sensitive to variations in trigger length and amplitudes. Considerable further work has resulted in the flip-flop of Dwg. SB-39272-2 in which the undesirable sensitivity to variations in trigger lengths and amplitudes has been largely eliminated. The results of tests on a single flip-flop of this type may be found in Engineering Notes No. E-42. It is important to realize that the results of this test apply only to the single flip-flop which was measured in the test and only with the individual pair of tubes used. In this note, no attempt was made to take into account variations in components. The variation in plate voltage that was used in making this test does not, in any way, give any reasonable indication of the difficulties that may be expected due to resistor value variations or variations in tube transconductance or tube plate currents. Tests are now underway by John J. O'Brien to determine the permissible tolerances for the resistors involved in this flip-flop circuit. Preliminary investigations indicate that corresponding pairs of resistors in the flip-flop may have to be matched to within better than 2%. The absolute value of these resistors may vary by at least 10% without causing any difficulty as long as corresponding pairs within the flip-flop are matched as previously stated.

A determination of the permissible variations in the characteristics of the 6AG7 tubes used in this flip-flop is still pending. However, it may be safely stated that only two characteristics of the tube will be of importance in the operation of the flip-flop; these are the voltage necessary to cut off plate currents and the plate currents at zero grid bias.

As may be seen from the results given in Engineering Notes E-42, the sensitivity to trigger signal inputs to the set and reset terminals of this flip-flop is much greater than that to signal inputs into the trigger input of the flip-flop. This feature may be undesirable in that it will require two different types of signals to be transmitted to the flip-flop and will, therefore, require that the source of the signal be determined by the destination of the signal within the flip-flop. For this reason it may be necessary to decrease the sensitivity to signals on the set and reset terminals. The electrode dissipations in this flip-flop have been kept to reasonable values, the plate dissipation being approximately 1.5 watts and the screen dissipation being approximately .9 watts; the maximum rated values are respectively 9 watts and 1.5 watts.

As previously mentioned, this investigation to date indicates that corresponding pairs of resistors in the flip-flop may have to be matched to within better than 2%. This may seem to be inconsistent with the fact that numerous flip-flops have been built in the Laboratory using 10% tolerance resistors and yet, all of these flip-flops, with a few exceptions, have worked reasonably satisfactorily. This is not quite the contradiction it may seem. Although the resistor tolerance is 10%, resistors taken from a given lot will be found to vary by less than 5% and the majority of them will only vary from a particular value by something of the order of 2% or 3%. Thus, the individual resistors picked for a flip-flop would have an excellent chance of being within 2 or 3%. However, for general practice, this purely chance arrival at suitable values would hardly be satisfactory and the results seem to indicate that it will be necessary to use 1% tolerance resistors for the aforementioned resistors in the flip-flop. Maintaining these close tolerances on the resistor value will relax considerably the requirements on the tubes to be used in the flip-flop and will allow a much wider variation in the tube characteristics without disturbing the operation of the flip-flop. Indications are that by using these close resistor tolerances, approximately 70 to 80% of standard 6AG7 will be usable in the flip-flop without any loss of reliability.

To again return to the question of excess sensitivity to signal inputs on the set and reset inputs of the flip-flops, this sensitivity may be reduced any desired amount by appropriately biasing the isolating crystals through which the signals are set into these input terminals.

By using the resistor tolerance values previously discussed, and selecting 6AG7 with standards that will eliminate only 20 to 25% of standard production tubes, and by appropriately biasing the isolating crystals in the set and reset inputs of the flip-flop, we may safely say that a flip-flop may now be built which always triggers on a trigger input or amplitude from approximately 11 volts to 50 volts and of duration from approximately 3/100 of a microsecond to 1/2 microsecond fed to any of the 3 inputs to the flip-flop and which will never trigger on a trigger of 4 volts or less amplitude regardless of trigger width; that is, we are now prepared to build flip-flops which can be approximately 100% reliable except for component failures.

It is of interest to note that only a small fraction of the flip-flops used in the computer will use the input to the cathode of the flip-flop; that is, the trigger input, for any purpose other than to receive the paired restorer pulses, that is, this input will not be used in any of the arithmetic operations in most of the flip-flops. This is not true of the flip-flop in the multiplier unit where they will be used directly in arithmetic operations. However, in a great many cases where it is true that the cathode input is used only for the restorer pulses, it may be possible to use a single trigger tube for groups of flip-flops on one panel, thus cutting down the number of tubes necessary. Work on this development is under progress at the moment and information on the success of the endeavor should be available soon. This change should, in no way, affect the reliability of the operation of the flip-flop.

Work to determine the permissible variation allowed in the characteristics of 6AG7 tubes for use in the flip-flop will be carried out by John J. O'Brien in the near future to determine test specifications to be used in selecting 6AG7 tubes from standard stock. The results of these tests will be made available as soon as possible.

LOUIS D. WILSON

LDW:maf:vh
August 18, 1947

ENGINEERING NOTES NO. E-57

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

TO:	6345 Engineers and Sylvania	6345
FROM:	J. J. O'Brien	Page 1 of 2
SUBJECT:	Test of Resistor Tolerances in Flip-flop Circuit SB-39272-2	Drawings: SA-39336 SA-39337
REFERENCE:	3JJOB-45-58	
NOTE:	Drawing SB-39272-2 already distributed with E-42	
DATE:	August 19, 1947	

Conclusion:

This flip-flop circuit with the two 5600 ohm and the two 2200 resistors at 1% tolerance and the other resistors at 5% should give stable operation because either tube when non-conducting will have approximately twice cut-off bias on its control grid. The test results also show that decreasing the tolerance to 1% on the 1600 ohm plate resistors makes practically no difference.

Introduction:

These Engineering Notes present the results of a test of the resistor tolerances in flip-flop SB-39272-2. Permissible variation in resistors will be decided upon first. Then these values will specify tolerances on the characteristics of the 6AG7 vacuum tubes used in the circuit. Another Engineering Note will cover the effect of tube variations.

The first criterion of stability in a flip-flop is the relation between the bias voltage on the control grid of either tube when it is non-conducting and the cut-off characteristic of the tube.

Test Method:

The resistors were measured on a General Radio impedance bridge, SM-3450. The tolerances were placed to have the worst cumulative effect on the circuit. This arrangement of tolerances is shown in Figure 1, Drawing No. SA-39337.

Three measurements of all circuit voltages were made with a Weston Voltmeter, 1000 ohms per volt, SM-702, using the 300 and 100 volt scales. First the voltages were taken with no tubes in the circuit, second with a 6AG7 tube in position V_1 of Figure 1 and third with the same tube in V_2. These three sets of circuit voltages were measured for various tolerance values.

One 6AG7 tube was used for all tests. On the tube checker it had the following characteristics.

The voltages of Column A are approximately those of the conducting tube in the flip-flop circuit and those of B, the non-conducting.

	A	B
Plate Voltage	50	90
Screen Voltage	90	90
Control Grid Voltage	0	-4.5
Plate Current ma.	30	1.5

The control grid voltage of Column B is by definition the cut-off voltage of this tube.

This 6AG7 is one of 40 measured on the tube checker under conditions A and B. Their average plate current = 30.41 Ma. and average control grid volts = -4.6.

In Table I, Drawing No. SA-39336 each row gives the value of the tolerances, arranged as in Figure 1, from which a circuit was constructed and tested. In all the circuit voltages measured only the control grid voltages are recorded in the table.

In row A, for example, when the 6AG7 was placed in circuit position V_1, with V_2 empty, it conducted with 0 control grid volts, and -6 volts bias was available for the control grid of position V_2. In the next column over, the same 6AG7 was placed in position V_2 and there was -14 volts bias available to the control grid of V_1.

The last column gives the minimum bias available to either tube when non-conducting. The relation between this minimum bias and the cut-off characteristic of a 6AG7 tube gives an indication of the circuit's stability.

Signed: J. J. O'Brien
J. J. O'Brien

JJO'B:vk

SA-39336

CIRCUIT TOLERANCE	LAST CONDUCTING IN POSITION V_1. CONTROL GRID VOLTS. V_1	V_2	LAST CONDUCTING IN POSITION V_2. CONTROL GRID VOLTS. V_1	V_2	MINIMUM BIAS AVAILABLE VOLTS
A. ALL RESISTORS 5% CATHODE RESISTOR +5%	0	−6	−14	+0.3	−6
B. ALL RESISTORS 5% EXCEPT 5.6K 1% CATHODE RESISTOR +5%	0	−7.5	−13	0	−7.5
C. PLATE RESISTOR 5% 5.6K & 2.2K 1% CATHODE RESISTOR +5%	0	−9.5	−11.8	0	−9.5
D. SAME AS C. EXCEPT CATHODE RESISTOR −5%	0	−9	−11.1	+0.3	−9
E. ALL RESISTORS 1% EXCEPT CATHODE RESISTOR −5%	+0.5	−9.5	−10.8	+0.05	−9.5
F. ALL RESISTORS 1% EXCEPT CATHODE RESISTOR +5%	0	−10	−11.5	0	−10

TABLE 1

6345 JJOB

JJOB 9/17/47 SA-39336

USED IN 6345 ENGINEERING NOTES E-57

JOB
9/17/47
SA-39337

6345

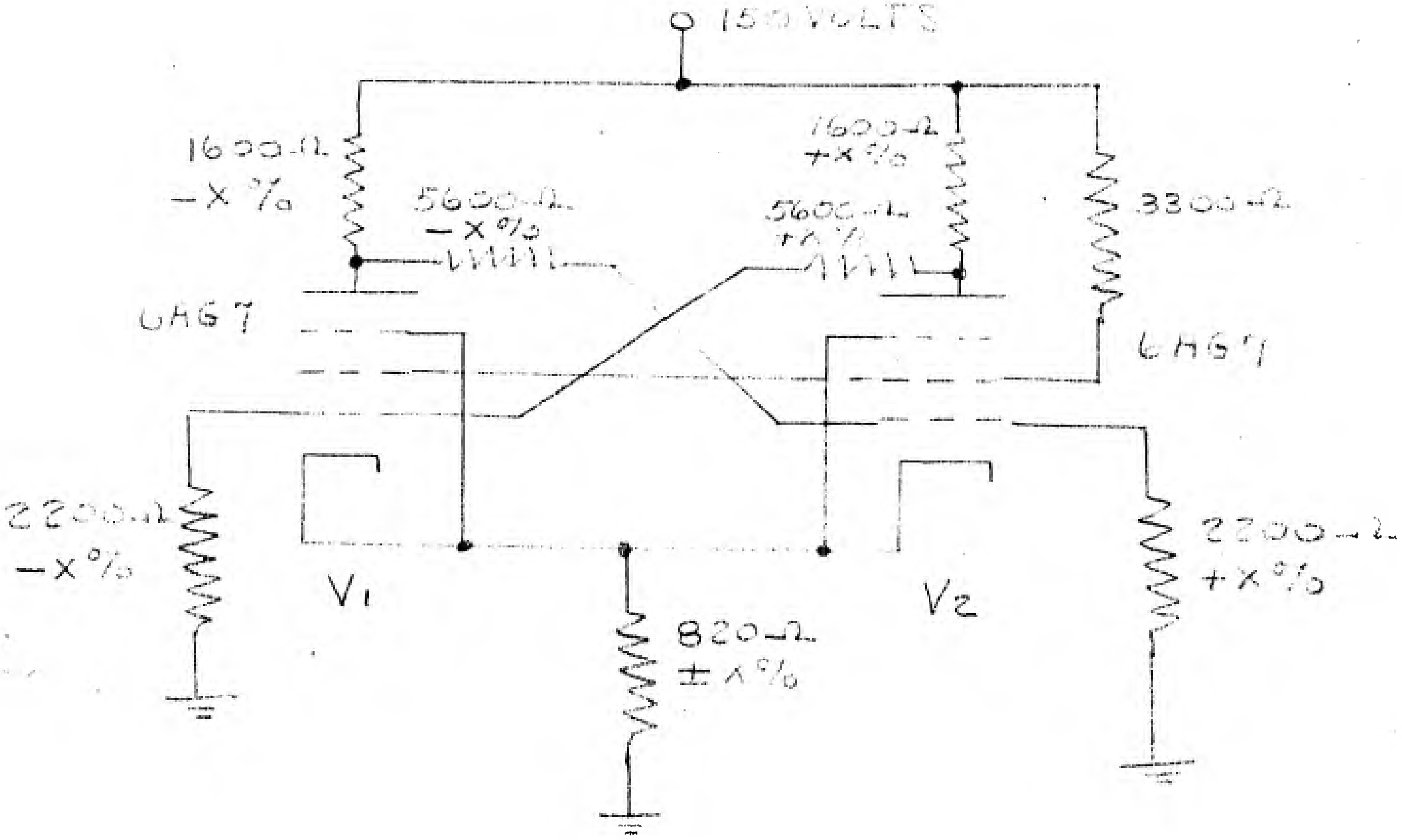


FIGURE 1 OF ENG. NOTES E-57

ARRANGEMENT OF
RESISTOR TOLERANCES
FOR WORST CUMULATIVE
[illegible] FLIP FLOP
CIRCUIT SB-39872-2

SA-39337

MEMORANDUM NO. M-99

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

TO: J. W. Forrester, H. Fahnestock, D. R. Brown, N. H. Taylor 6345

FROM: J. O. Ely

SUBJECT: Precision Resistors for Use in Flip-Flops

DATE: August 26, 1947

A survey of the available types of precision resistors has been made for the purpose of finding a type suitable for use in flip-flops incorporated in W.W.I. and W.W.II. Because of the close tolerances to which these resistors must be held, the following points were considered:

1. Resistance units should be purchased with an initial tolerance rating of ±1%.

2. Wire-wound or metallic-film types are preferable to composition, metallized carbon, or carbon-film types.

3. Units should be operated as far below rating as is consistent with the requirement that resistors be reasonably compact.

With the above requirements in mind, three types of resistors are recommended. Order of preference is the same as order of listing. The types are:

1. I.T.E. No. 116-B. This resistor is a single-layer inductive wire-wound unit. Used as a power resistor its rating is 8 watts, but a more reasonable rating as a precision resistor is 3 watts. Physical construction of the unit is very rugged and will tend to give excellent stability. Tests in our laboratory indicate a temperature coefficient of about ±0.03% per degree centigrade. Preliminary checks in the laboratory indicate that this

resistor type will be satisfactory for use in high-speed flip-flops in spite of its inductance. J.J. O'Brien will make further tests to determine whether any adverse effect on operation will result from use of these resistors. A trial layout of the "Carry Flip-Flop" in the accumulator register is being made by Walter Cook to determine the best method of mounting. Price for ±1% tolerance units will be about fifty cents each. Delivery is not certain but will be about six weeks.

2. Continental Carbon "Nobleloy X" type. This resistor is a metallic film type. It is available rated at ½, 1, 2, and 5 watts as a precision resistor. Physical construction is good. Radial pigtail leads are furnished on all sizes, and only the 5-watt size is large enough to require additional mounting support. The unit is slightly inductive, but has less inductance than the wire-wound type. Manufacturer's specifications indicate that stability will be quite adequate to meet our requirements. Temperature coefficient is -0.05% per degree centigrade. Price for ±1% units will be less than forty-cents each. Manufacturer's representative (Holliday-Hathaway Sales Co.) claims delivery on any resistance value can be made in one week.

3. Sprague "Koolohm" type 5 NIT. This is a non-inductive wire-wound resistor using an Ayrton-Perry type winding on a ceramic rod. Rating as a power resistor is five watts. For use as a precision resistor the rating should be not more than two watts. Normal stock tolerance is ±5% but manufacturer's literature indicates that closer tolerances can be furnished. The largest

stock resistance value is 5000 ohms. No data on temperature coefficient or stability are available, but the resistor should be comparable to the I.T.E. resistor mentioned above. Axial pigtail leads are standard but some additional mounting support will be required. No quotation on price and delivery has been secured. Use of this type is recommended only if laboratory tests indicate that the inductance of the first two types affects operation adversely.

John O. Ely
John O. Ely

JOE/rp

Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: FLIP-FLOP LIFE TEST RACK - FIRST 500 HOUR RUN

To: 6345 Engineers

From: A. B. Horton, Jr. and J. J. O'Brien

Date: October 3, 1947

Introduction

In order to test the operation and reliability of the 6AG7 flip-flop circuit proposed at present for use in WWI, a test rack consisting of 10 flip-flop units has been constructed and set into operation. Front and rear views of this rack, together with its auxiliary equipment rack, are shown in Drawings A-31001 and A-31002. The 10 flip-flop units and their tubes are identified in Drawing SA-39357.

All power for the rack is now being supplied by isolated motor-generator sets. Because of this isolation, it is expected that all errors made by the flip-flops during a test period are attributable to the flip-flops themselves or the restorer pulse generator, and not to external effects such as power line transients, etc.

A test run of 500 hours has been conducted.

Results

During the 500-hour test period, it is known that flip-flops 3A, 4A, 4B, 5A, and 5B made at least one error. Flip-flop 1A (the counter flip-flop) made no errors during the period.

With the exception of one tube, the 500 hours of continuous operation had no appreciable effect on either tube characteristics or resistor values.

Discussion

1. CONSTRUCTION OF RACK

The circuit schematic of the flip-flop under test is shown in Drawing SB-39281-1. It should be noted that no buffer amplifiers are present in this circuit. A tube type 2C51, which drives the neon indicating lamps, is capacitively-coupled to the plates of the flip-flop.

Restorer pulses are provided on two lines at a repetition rate of 100,000 cycles per second by a modified restorer pulse generator, the circuit schematic of which is shown in Drawing SB-39359. The time interval between the two restorer pulses is 0.5 microsecond. Each of the two output lines from

the restorer pulse generator drives 5 flip-flop units in parallel, and each line is terminated only at its end by the characteristic resistance (100 ohms) of the line. No line termination is provided at the inputs of the various flip-flops.

Initially, flip-flop d-c plate power was provided by voltage-regulated power supplies. Five such supplies were used, each driving 2 flip-flop units. D-C plate power and bias for the restorer pulse generator was supplied by the Building 32 wall supplies. However, transients in the 115-volt A-C line and in the wall supplies caused the flip-flips to make errors. In order to eliminate these transients and their effects, all power (except filament power) required by the rack and pulse generator is now being supplied by motor-generator sets located in the Building 32 generator room. Filtering equipment for each motor-generator set is located on the auxiliary rack. Schematics of the filtering equipment are shown in Drawing SA-39345.

Flip-flop 1A is provided with a sensitive relay and electromagnetic decimal counter for detection of its errors. The relay and counter are connected in the plate circuit of the 2C51 as shown in Drawing SA-39358. Similar counting equipment will be installed in the remaining flip-flop circuits upon reception of additional counters. By means of the counter in conjunction with the neon indicating lamps, it is possible to ascertain the exact number of errors made by flip-flop 1A during a test period. Due to the lack of counters in the remaining 9 flip-flop circuits, it is only possible to tell whether or not each of these flip-flops made an odd number of errors during a test.

II. EFFECTS OF 500 HOURS OF CONTINUOUS OPERATION

A. On Resistors:

Table SA-39351 lists the voltage from the control grid connections to ground on each flip-flop unit, with all the tubes removed. The difference between this voltage on one tube of a flip-flop and the same voltage on the second tube is the circuit's most important voltage. This voltage difference also gives an indication of the arrangement of tolerances in the two bleeders of the circuit. If all the resistors of the bleeders had 1% tolerances arranged to give the worst cumulative effect, the computed voltage difference = 1.1 volts, and for all 5% resistors = 2.1 volts.

The 10 flip-flop circuits were built with resistors having at least 5% tolerance. As shown in Table SA-39351, at the start of the run, time = 0, this voltage difference for flip-flop 3A is 32-29.9 = 2.1 volts. With this exception, 3A, all the other flip-flops have a voltage difference of about 1.1 volts or less. So for these 9 flip-flops the chance arrangement of the 5% resistors gave the same effect as construction with 1% resistors.

At the end of the run, time = 500 hrs., Table SA-39351 shows no change in the voltages. This indicates either no change in the resistors or whatever changes took place compensated one another in the desired fashion.

The bleeder resistors were used at less than 50% rated dissipation, except the 5600 ohm resistor which dissipated 75% of its rating.

B. On Tube Characteristics:

Twenty new tubes used in the flip-flops were tested on the tube-tester

at the start of the run. The plate current of the tube was measured with electrode voltages approximating those of the conducting tube in the flip-flop circuit, and then the control grid voltage, necessary to cut the tube off, was measured with electrode voltages approximating those of the non-conducting tube of the flip-flop. These two sets of voltages are given in the Note of Table SA-39354.

The tubes were paired off according to their plate current and inserted so that each flip-flop had tubes with balanced plate currents. In flip-flop 1A, from Table SA-39354, V_1 = 27 ma. = V_2.

Because of the preliminary testing on the life-test rack, these tubes were in operation for probably 600 hours.

At the end of the run, the tubes were again measured in the tube-tester under the same conditions. These plate currents and control grid voltages are shown in Table SA-39354 under the columns headed Time = 500 hours.

A second Table SB-39352, gives all the circuit voltages with the tubes in, first with one conducting, then with the other. The table includes voltages from the same points at the end of the run. For these measurements the flip-flops were not being triggered.

In Table SA-39354 only one tube, $2BV_1$ shows a radical change in characteristics. However, this change is not indicated in the circuit voltages of Table SB-39352. The increase of 116% in the bias voltage necessary to cut the tube off would not show in Table SB-39352, because there was -10 volts available to the control grid anyhow. The 25% increase in plate current does not show in Table SB-39352.

C. Errors:

Only one counter was available during the run. The mistakes of flip-flop 1A alone could be counted exactly. The neon bulbs of the other nine would indicate an odd number of mistakes but not an even number.

If, during an interval, 1A made no mistakes and each of the other nine indicated either none or an even number of mistakes, then it was assumed probable that no mistakes were made.

The flip-flop life test rack was a 10-digit register. Each digit was reversed every 24 hours.

Table SA-39353 is a log of the errors made. For the first 237 hours no mistakes were made, using the probability described above. Next, there was an interval of 16 hours in which 5 flip-flops made an odd number of errors. Many possible disturbances that could have happened during this period were checked on with no result.

For the next 176 hours no mistakes were indicated. During the following interval of 64-1/2 hours, flip-flop 5A made an odd number of mistakes. This interval is so long because the rack was not observed from a Friday night until the following Monday morning. For this period, the digits were not changed. The final 6-1/2 hours were merely to bring the run to an even 500 hours.

The exact number of errors of flip-flop 1A, which had the counter, was 0 throughout the 500 hours.

III. FUTURE INVESTIGATIONS

A. Second Run:

The next run of the flip-flop life test rack will investigate the possibility of using one driver to feed restorer clock pulses to the 10 flip-flops. The present method has a separate driver for each flip-flop.

Since the same circuit components and tubes will be used again, this will also continue some aspects of the first run for a few hundred more hours.

Signed A.B. Horton, Jr.
A. B. HORTON, JR.

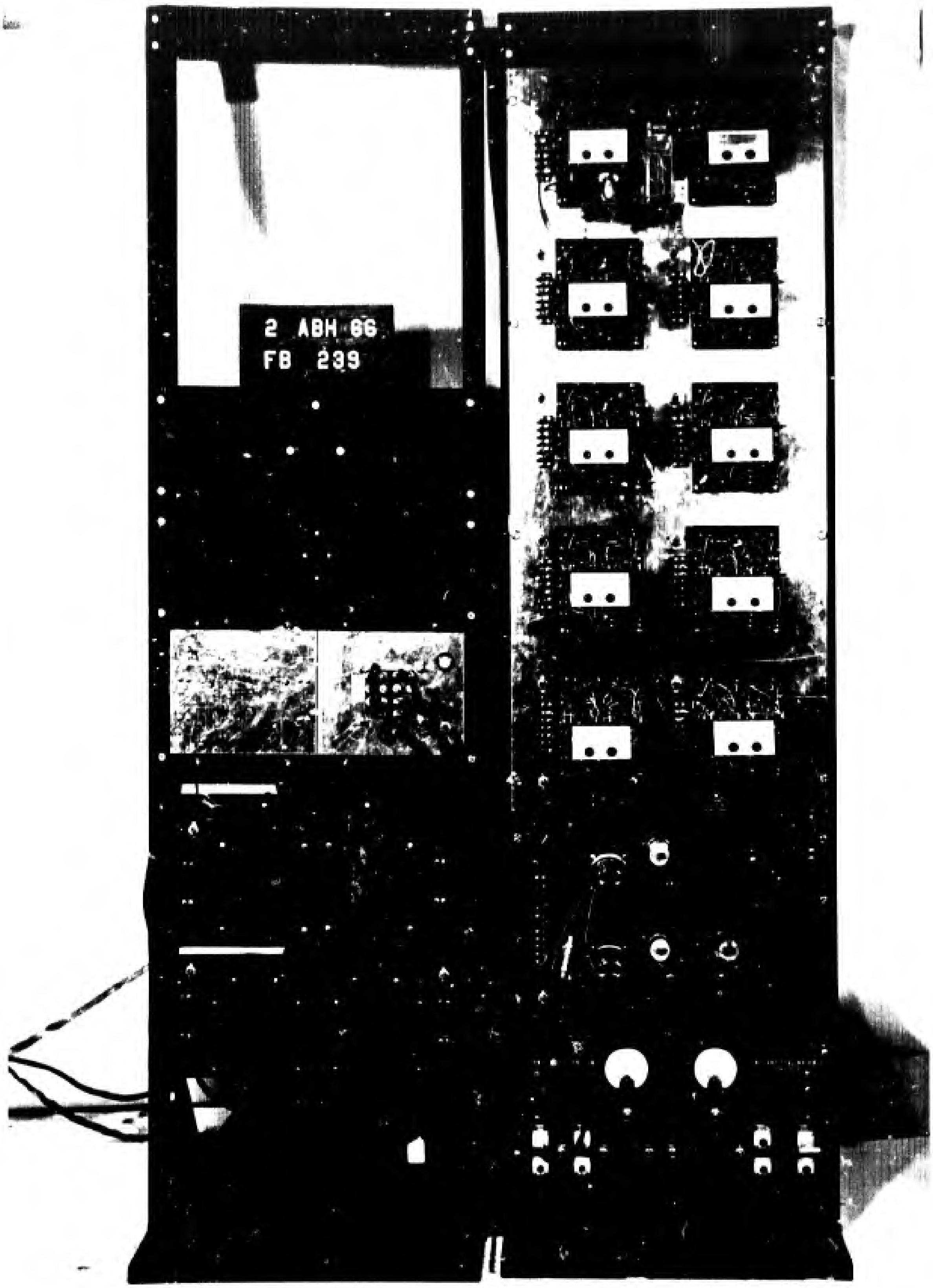
John J. O'Brien
JOHN J. O'BRIEN

Drawings:

A-31001
A-31002
SA-39357
SB-39281-1
SB-39359
SA-39345
SA-39358
SA-39351
SA-39354
SB-39352
SA-39353

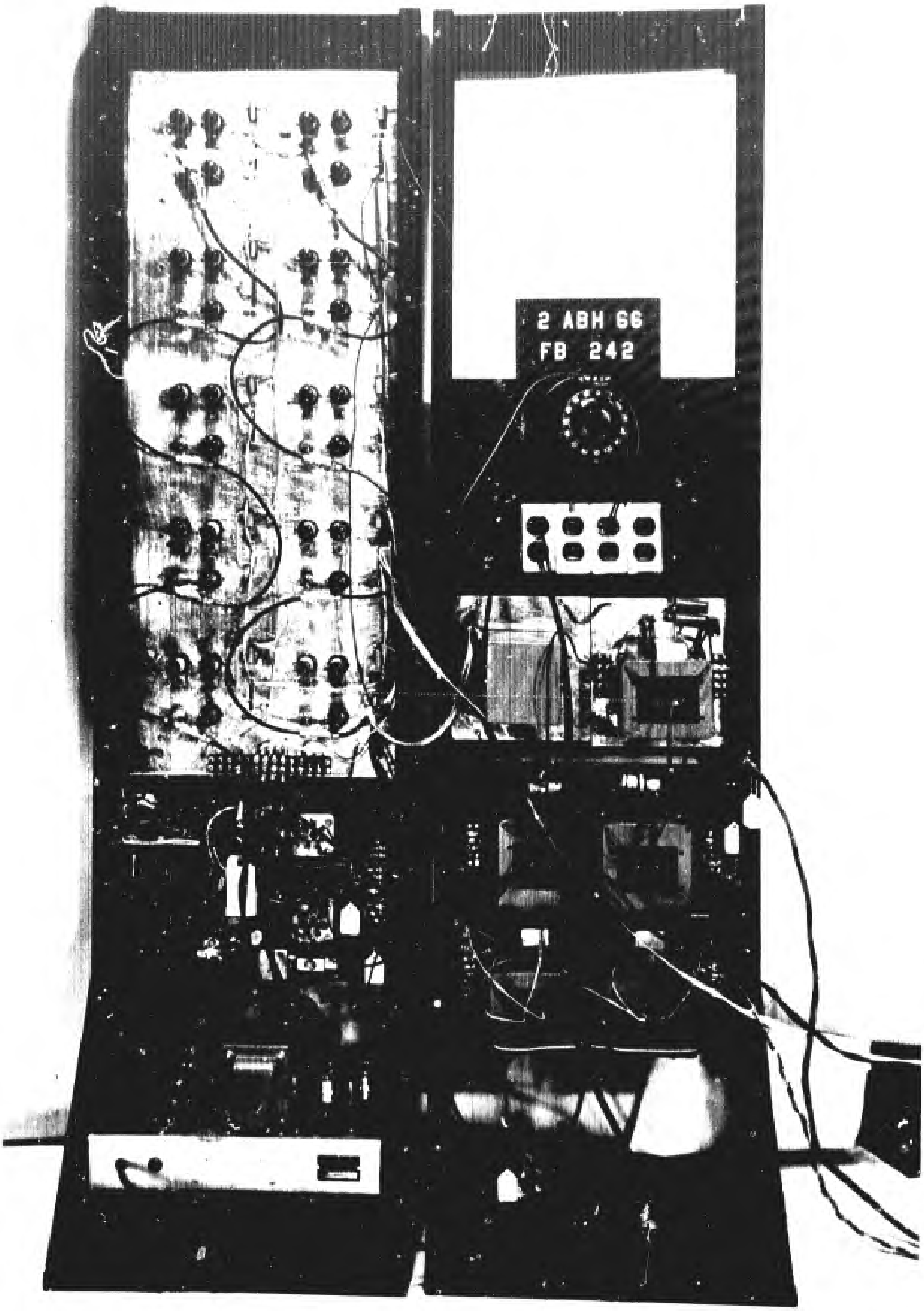
List of References:

2ABH 30-73
3JJO'B 67-69, 91-94, 114-122



FRONT VIEW, FLIP-FLOP LIFE-TEST RACK AND AUX. RACK

A-31002

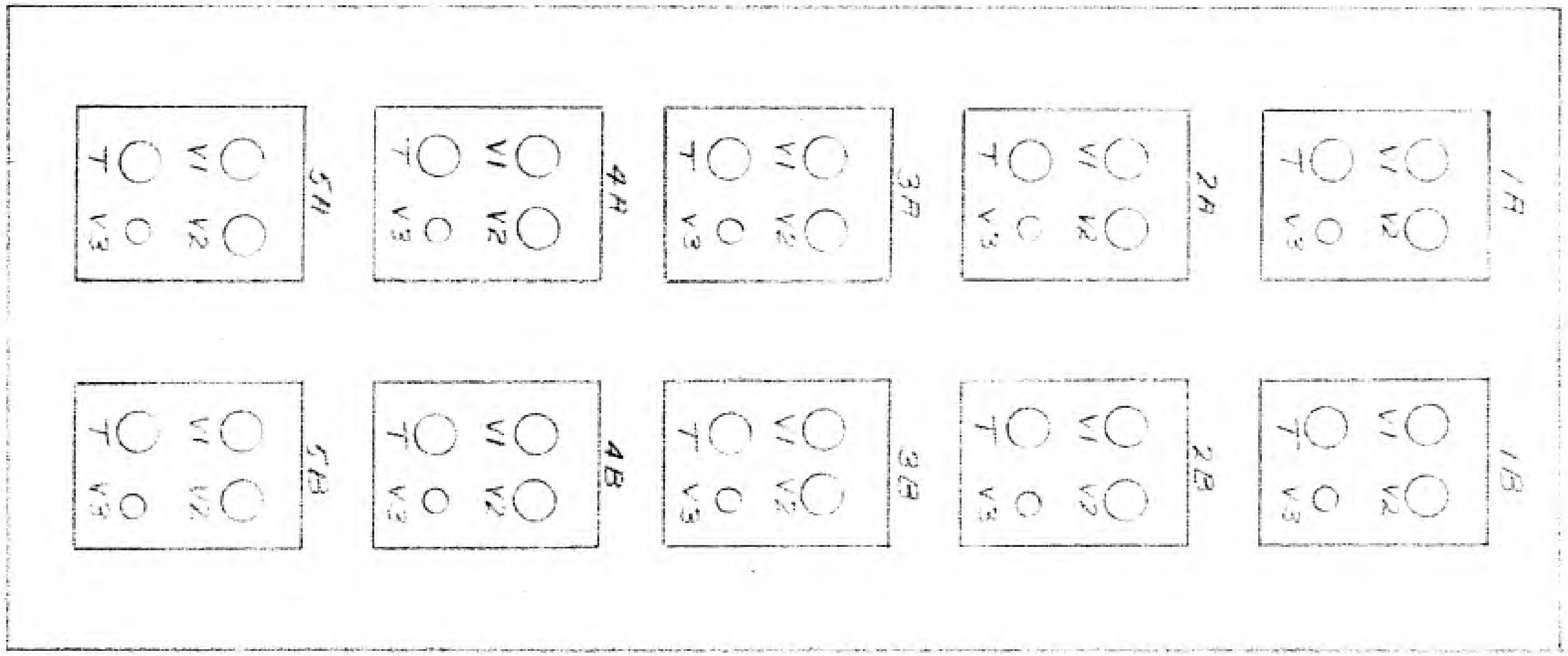


REAR VIEW FLIP-FLOP LIFE TEST RACK AND AUX. RACK

USED IN 6345 ENGINEERING NOTES E-64

-31002

SA-39357



TUBE DESIGNATIONS:

V1 and V2 - Flip Flop Tubes

T - Trigger Tube

V3 - Neon Lamp Driver

FLIP-FLOP LIFE-TEST RACK:

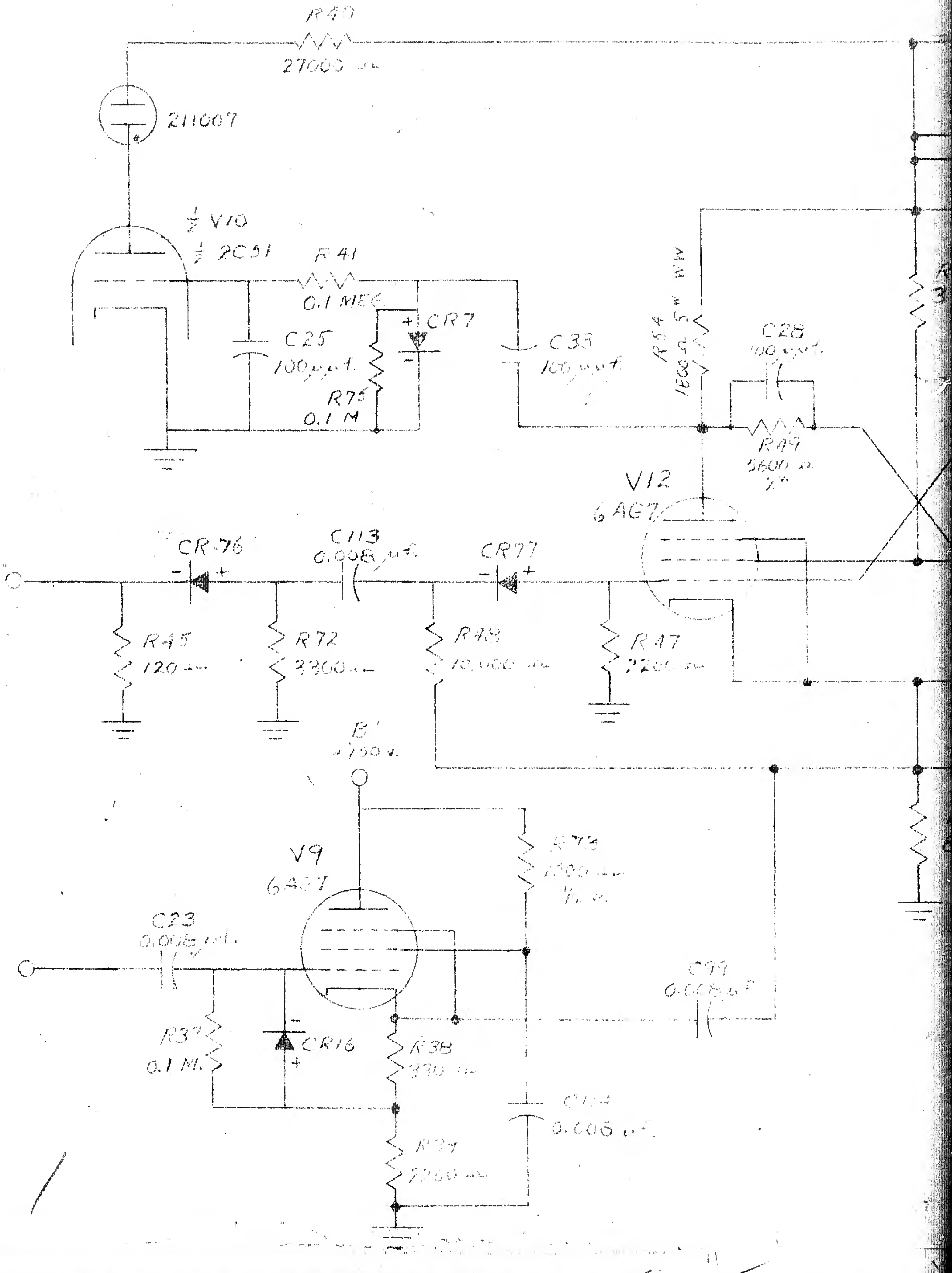
FLIP-FLOP AND TUBE DESIGNATION

6345
ABH

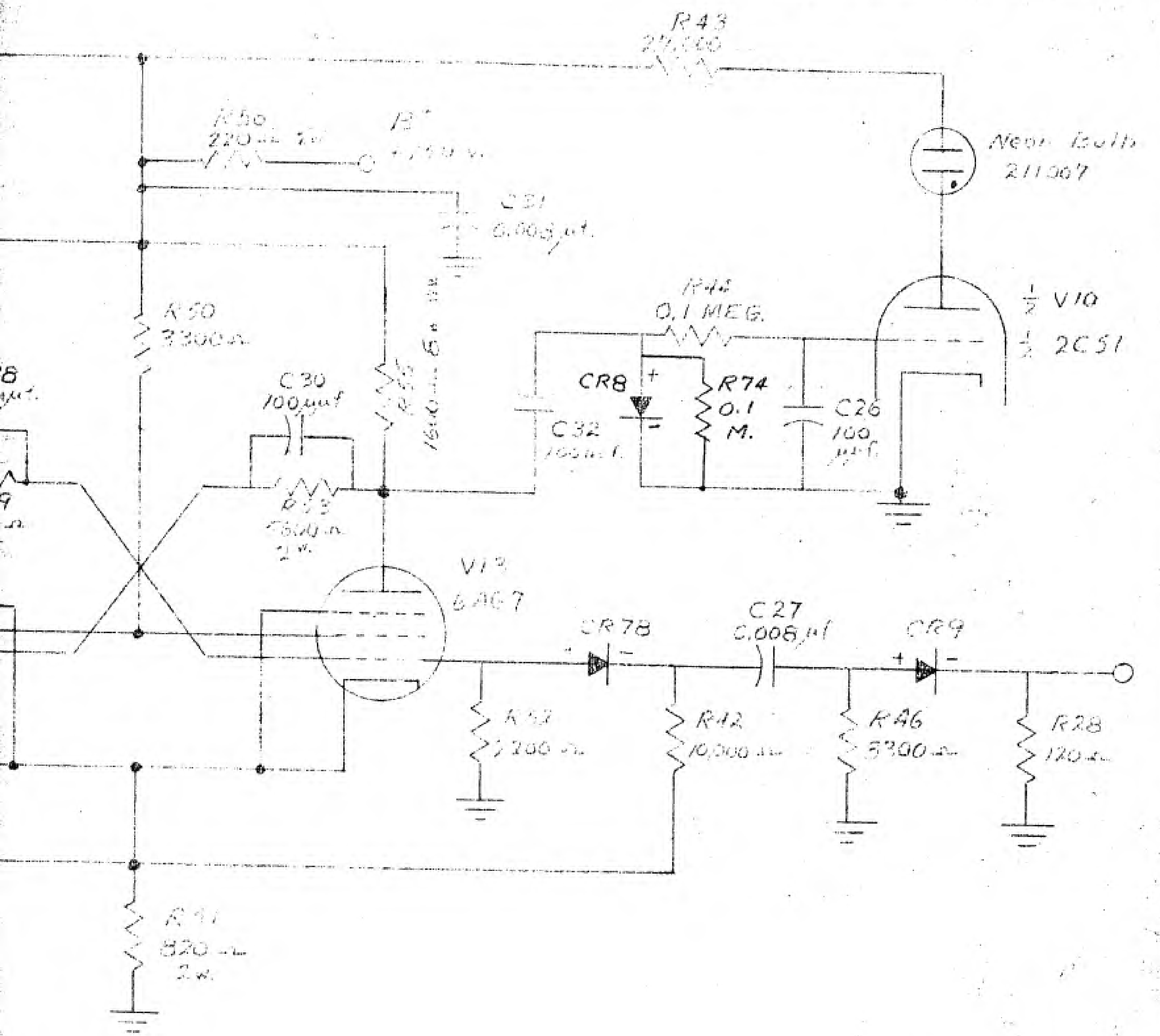
ABH
10/3/47

SA-39357

SB-39281-1



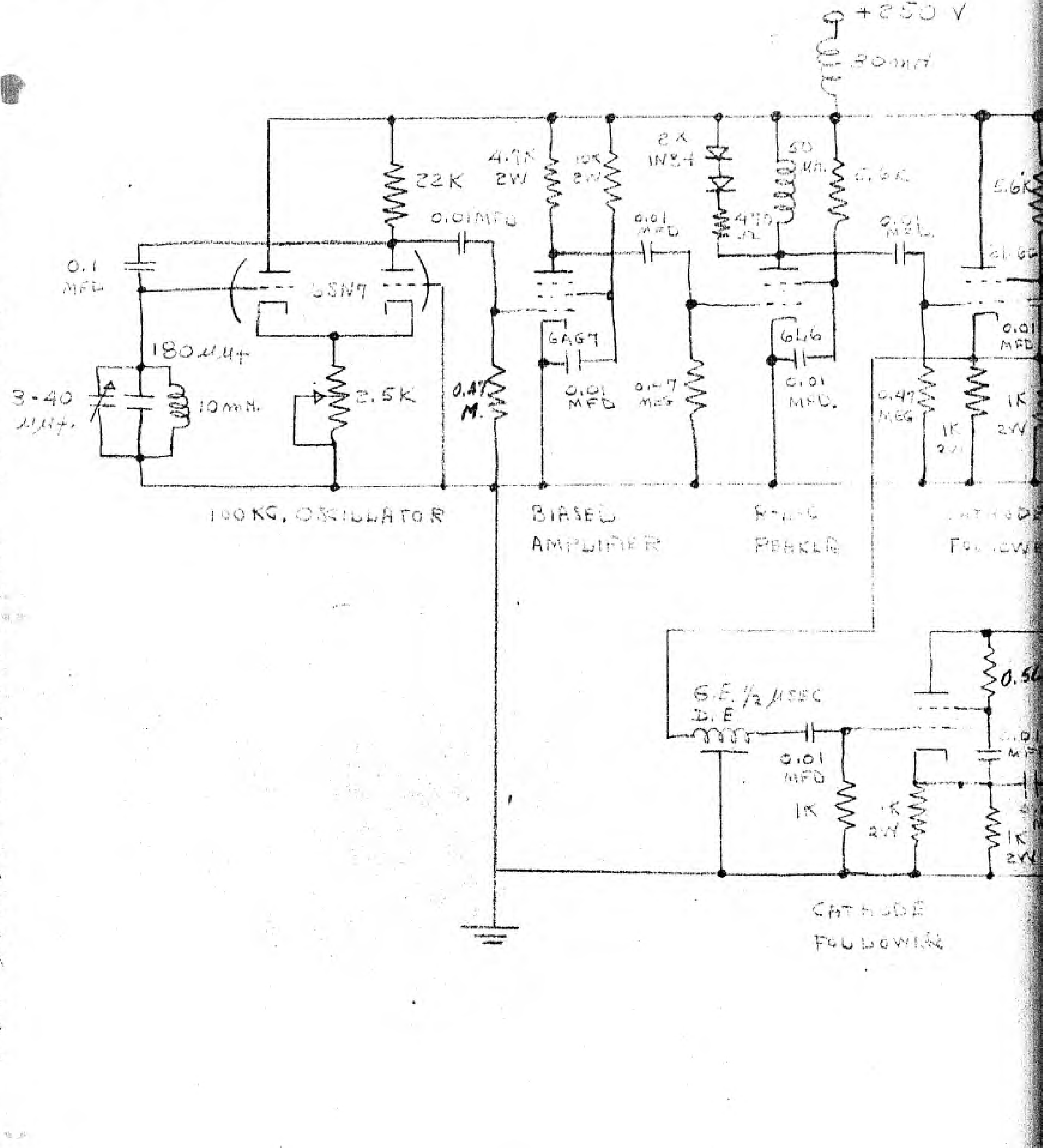
R40
1/2 V10
1/2 2C51
R41
0.1 MEG
CR7
C25
C33
R75
0.1 M
R54
C28
R49
5600 Ω
V12
6AG7
CR76
C113
CR77
R45
R72
R48
R47
V9
6AG7
C23
R37
0.1 M.
CR16
R38
C99
0.008 μf

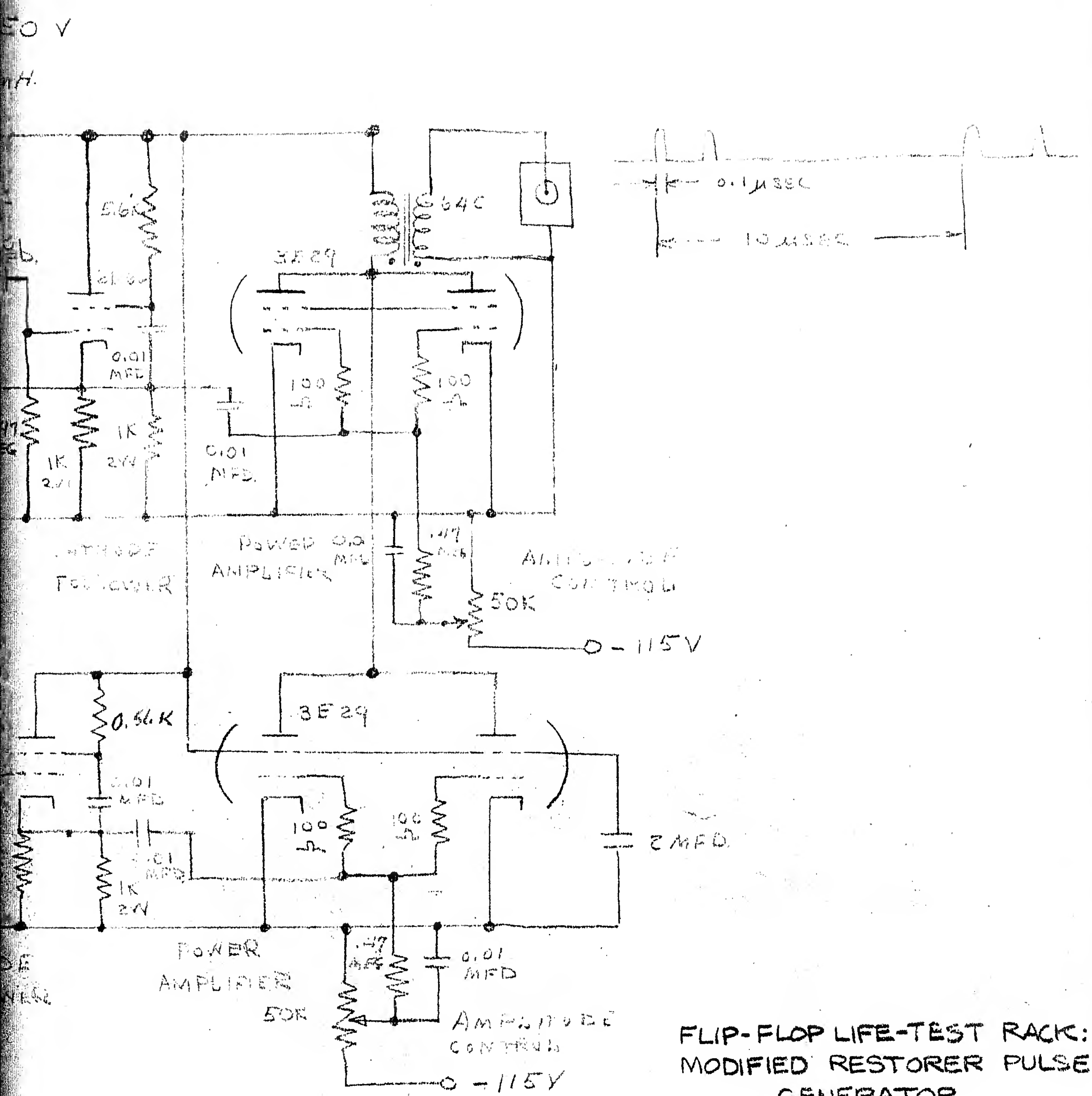


TEST FLIP-FLOP SCHEMATIC

6345
ABH
7/7/47
ABH
SB-39281-1

SB-39359


+250 V
30 mH
22K
0.01 MFD
4.7K 2W
10K 2W
2X 1N34
50 MH
470 Ω
0.01 MFD
5.6K
0.1 MFD
6SN7
6AG7
6L6
180 μμf
3-40 μμf
10 mH
2.5K
0.47 M.
0.01 MFD
0.47 MEG
0.01 MFD.
0.47 MEG
1K 2W
0.01 MFD
100 KC. OSCILLATOR
BIASED AMPLIFIER
PEAKER
6.E. ½ μSEC D.E
0.01 MFD
1K
1K 2W
CATHODE FOLLOWING



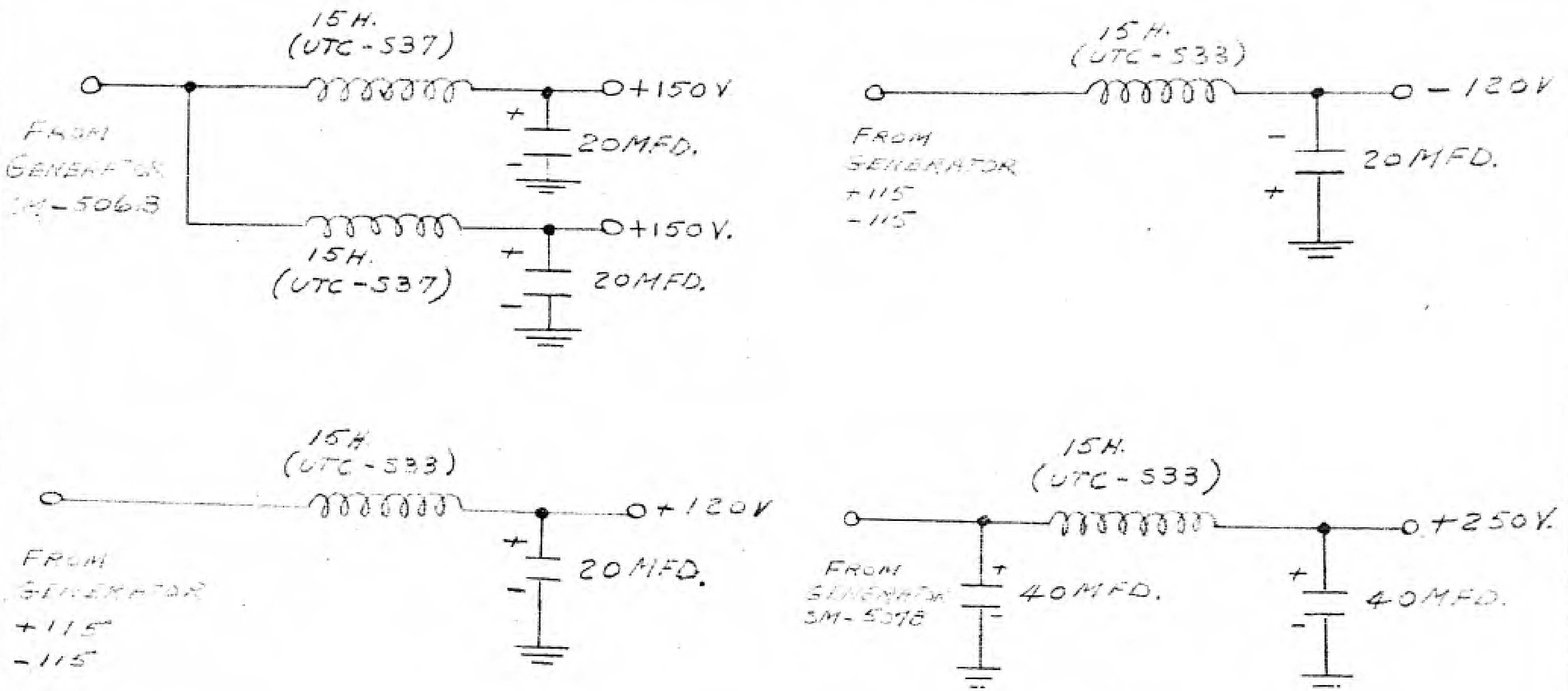
FLIP-FLOP LIFE-TEST RACK:
MODIFIED RESTORER PULSE
GENERATOR

2

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

6345	ABH 10/3/47	
ABH	SB-39359	

SA-39345

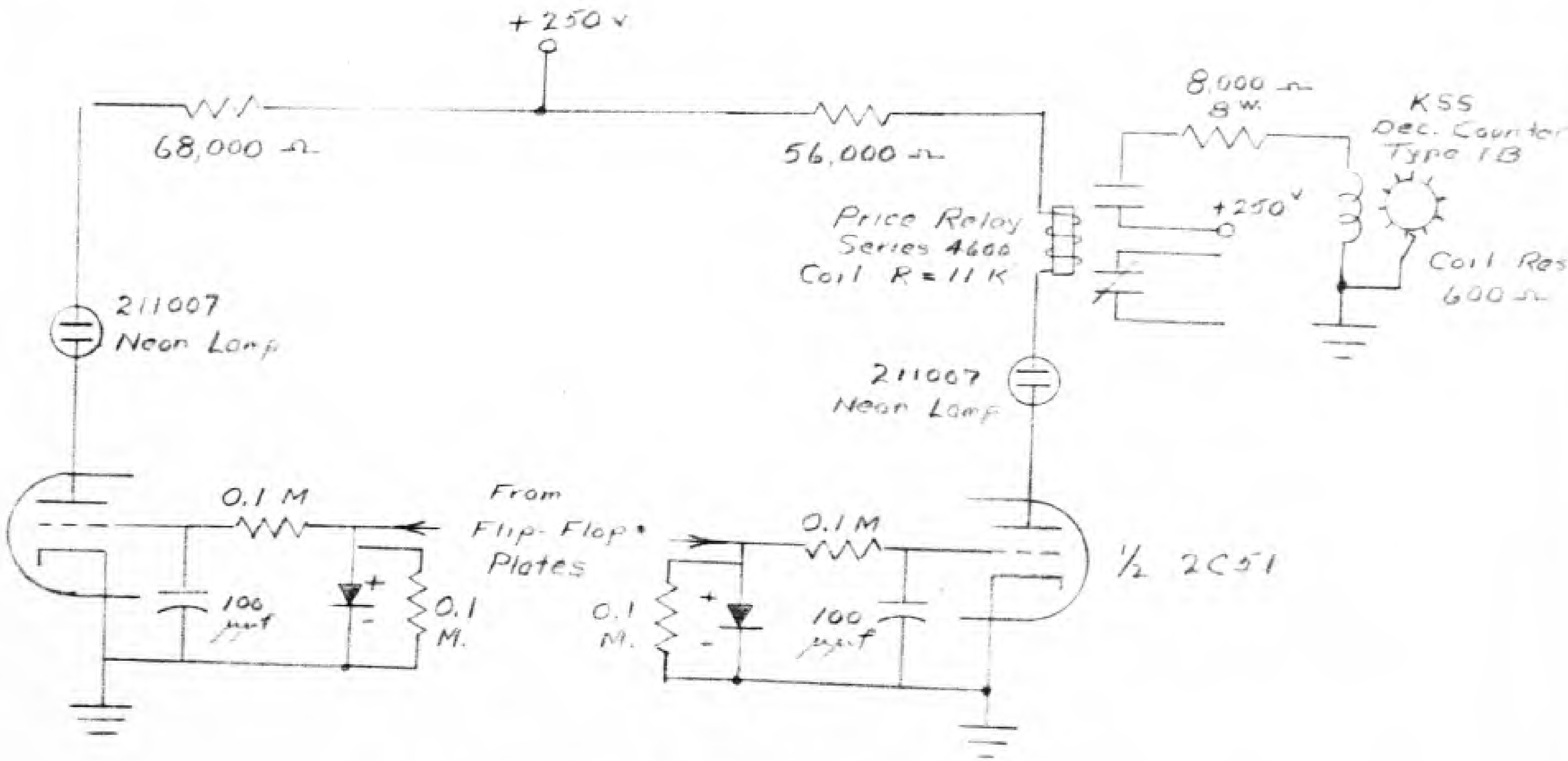


SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO. 6345

FILTERS USED IN FLIP-FLOP LIFE-TEST RACK

SCALE:		DR. J. J. GR. 9-23-47	SA-39345
ENG. J. J. G.B. 9-23-47	CK.	APP.	

SA-39358



FLIP-FLOP LIFE-TEST RACK:
FLIP-FLOP 1A COUNTER CIRCUIT

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6345	ABH 10/3/47
ABH	SA-39358

SA-39351

VOLTAGE FROM CONTROL GRID TO GROUND
ALL TUBES OUT

FLIP-FLOP No.	V_1 VOLTS, TIME = 0	V_1 VOLTS, TIME = 500 HRS.		V_2 VOLTS, TIME = 0	V_2 VOLTS, TIME = 500 HRS.
1A	31.9	32		32	32.
1B	32	32		32.1	32.4
2A	32	32.2		33	33.1
2B	32.3	32.4		31.9	32
3A	32	31.9		29.9	30.
3B	31.2	31.1		32.5	32.1
4A	31.9	32.		32.	32.
4B	31.1	31.		31.1	31.
5A	32.	32		31	31.
5B	32.4	32.5		32.2	32.2

SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO.

TABLE-INDICATING RESISTOR CHANGE [illegible] FLIP-FLOP LIFE TEST RACK. RUN No. 1.

SCALE:	DR. JJOB 9/30/47		SA-39351
ENG 9/30/47 J. J. O'B.	CK.	APP.	

"ALBANENE" NO. 106L K&E CO., N.Y.X

TUBE No.	PLATE CURRENT UNDER (A) TIME = 0 MA.	PLATE CURRENT UNDER (A) TIME = 500 HRS. MA.	C. GRID VOLTAGE UNDER (B) TIME = 0 -VOLTS.	C. GRID VOLTAGE UNDER (B) TIME = 500 HRS. -VOLTS.
1AV1	27	26.5	5.5	6.1
1AV2	27	27.5	4.4	4.2
1BV1	27	29.5	4.0	4.
1BV2	27.5	25	4.5	4.7
2AV1	27	32	5.	4.8
2AV2	27.5	27.5	4.6	4.3
2BV1	30	22.5	4.4	9.5
2BV2	30	28	4.2	4.2
3AV1	32	27	4.2	4.1
3AV2	32	28	4.8	4.7
3BV1	31	35	4.9	4.8
3BV2	31	26	5.2	6.
4AV1	35	35	4.7	4.7
4AV2	35	33	4.5	4.4
4BV1	32.5	32.5	4.4	4.1
4BV2	32.5	31	3.0	4.4
5AV1	30	27.5	4.4	4.4
5AV2	30	29.5	4.4	4.3
5BV1	28	27.5	4.7	4.6
5BV2	28	31.0	5.2	5.1

NOTE:

	(A)	(B)
PLATE VOLTS	50	90
SCREEN "	90	90
C.GRID "	0	?
PLATE CURRENT, MA	?	1.5

SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO.

CHARACTERISTICS OF TUBES USED IN FLIP-FLOP LIFE TEST RACK - RUN No. 1

SCALE: | DR. | ENC 9/24/47 J.J.O'B. | CK. | APP.

SA-39354

SB-39352

FLIP-FLOP No.	CIRCUIT POINT	V1 CONDUCTING: TIME = 0, V1 VOLTS	TIME = 500 HRS, V1 VOLTS	TIME = 0, V2 VOLTS	TIME = 500 HRS, V2 VOLTS	V2 CONDUCTING: TIME = 0, V1 VOLTS	TIME = 500 HRS, V1 VOLTS	TIME = 0, V2 VOLTS	TIME = 500 HRS, V2 VOLTS
1A	PLATE TO GND.	92	92.5	123	124	121	124	53.1	83
	C.GRID " "	34	34.	27.1	27.8	24.2	24	34.1	34.5
	CATHODE " "	33.8	33.9					33.8	34
	SCREEN " "	94	93.8					120.	121
1B		82	82.9	121	122	122	124	54.8	85
		35	35.	24.3	24.9	25	25.2	35.	35.1
		34.6	34.					33.8	34.
		120.	121.					117	120.
2A		87	87	122	124	122	123	83.5	83.4
		35	35.1	26.8	26.8	25	25	35.4	35.9
		34.5	34.7					34.9	34.9
		105.	107.					110.	112.
2B		84.	85	121	122	122	124	81	80.5
		35.2	35.6	25	25.1	24.1	24.3	34.6	35
		35	34.9					34	34.5
		110	111.					120	121.
3A		82	82	121	123	122	122	52	81.9
		34	34	22.9	22.9	24	24	33	33.
		33.3	33.4					32.5	32.5
		111.	112.					110.	112.
3B		55	85.1	121	122	120	122.5	54.2	84.3
		34.8	35.	25.5	25.7	24	24.3	35.9	36.
		35.	35.					35.	35
		108.	110.					111.	112

3B		85 34.8 35. 108.	85.1 35. 35. 110.	121 25.5	122 25.7	120 24	122.5 24.3	54.2 35.9 35. 111.	84.3 36. 35 112
4A		79 35.5 36. 120	78.8 35.8 36. 121.	122 23	122 23.3	120 23	122.5 23.1	79.6 36 36 119	79.1 36. 36. 120.
4B		81.2 34.4 34.8 115.	81.2 34.6 34.9 116.	121 23.2	123 23.5	121 23	122 23	80.2 34.9 34.9 120.	80.2 34.9 34.8 121.
5A		81.9 35. 34.9 120.	81.6 35 35. 123.	122.5 23.1	124 23.2	121 24	123 24.4	82 34.5 34.5 121.	82.1 34.8 34.6 123.
5B		84. 34.4 34. 113.	84.1 34.5 33.9 114.	122 25.1	124 25.1	121 26.2	124 26.2	88 34.8 34. 101.	87.1 35. 34.1 103.

TABLE OF CIRCUIT VOLTAGES
IN FLIP-FLOP LIFE TEST RACK
RUN NO. 1

NOTE:
FLIP-FLOPS
NOT BEING TRIGGERED

6345
JJOB
JJOB
9/30/47
SB-39352

SA-39353

TIME HOURS	INTERVAL HOURS	FLIP-FLOP No. IN WHICH AT LEAST 1 ERROR IN INTERVAL
0 TO 237	237	NONE
237 TO 253	16	3A 4A 4B 5A 5B
253 TO 429	176	NONE
429 TO 493½	64½	5A
493½ TO 500	6½	NONE

SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO. 6345

LOG OF ERRORS
FLIP-FLOP LIFE TEST RACK - RUN No. 1

SCALE:	DR. JJOB 2/3/47	SA-39353
ENG. J.T.OB	CK.	APP.

"ALBANENE" NO. 186L K&E CO., N.Y.X

Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: FLIP-FLOP LIFE TEST RACK RUN NO. 2

To: J. W. Forrester, H. Fahnestock, N. Taylor, D. Brown, A. B. Horton

From: J. J. O'Brien

Date: November 10, 1947

Conclusion:

For 302 hours, the 10 flip-flops of the rack received restorer pulses from a single driver. Previously 10 drivers, cathode follower trigger tubes, had been used. No errors were recorded in the period. This makes the elimination of the individual drivers in the computer look feasible. However, there are a few other tests to be conducted before this method of triggering is completely accepted.

After 802 hours of operation, Table SA-39444 indicates no change in resistor values.

The twenty 6AG7 tubes of Run No. 1, 500 hours, were not used in the two preruns but in Run No. 2. Of these twenty tubes, after the first 500 hours, two could not be used in the second run. Table SA-39443 shows a general decrease in plate current with operating time and little change in control grid bias necessary for cutoff. Table SA-39445 gives no changes in the circuit voltages.

I. Introduction:

At present each flip-flop circuit has a 6AG7 cathode follower tube which feeds the low cathode impedance of the flip-flop, and provides a suitable circuit point for the proper terminating and mixing of 1000 ohm and 100 ohm lines. Now only about 20% of the flip-flops in the computer receive signals other than restorer triggers on their cathodes. If a group of flip-flops, which receive only restorer pulses, perhaps all on one digit panel, could be fed from a single driver, there would be a large saving in tubes and other components.

The primary purpose of the second run of the life test rack was to see if feeding all the cathodes from a single driver introduced any instability. In this fashion the rack was run for 302 hours.

II. Loaded Line:

To get a general idea of the nonlinear impedance of a flip-flop cathode, triggers of various amplitudes and lengths were fed to cathode from a low impedance source and through a series resistor, which was also varied. The waveforms on either side of this resistor were compared and an approximate value for the cathode impedance was calculated. For the flip-flops of the life

test rack this impedance was between 160 ohms and 500 ohms.

Hanging 10 such impedances at intervals along a 100 ohm line loads it and changes its transmission characteristics. The input impedance or characteristic impedance of the line thus loaded was measured using the method described above. This impedance ran from 12.6 ohms to 36 ohms. The higher impedance was selected as a working value because it resulted from measurements with short pulses that would eventually be used.

The total delay in this line was 0.05 microseconds.

III. Driver:

Drawing No. SA-39372 shows the two tube driver used for the rack. The first sharp cutoff 6AG7 tube reduces the amplitude of the necessary trigger input, and is easily biased to keep noise from passing through the driver from the line. The second 6Y6 tube supplies the necessary current through a 3 to 1 transformer to the loaded line. The duty cycle of the driver is only 1 to 50.

IV. Tube Failures:

After the first run of 500 hours one tube $2BV_1$ showed a great increase in the control grid bias necessary to cut it off. In the second run it was replaced by 2AT which had been the trigger tube of flip-flop No. 1A during the first run. At the very start of the second run tube $3BV_2$ failed having a short from control grid to cathode. It was replace by tube 1AT. During their use these tubes have been kept from any mechanical shocks or damage.

V. Next Run:

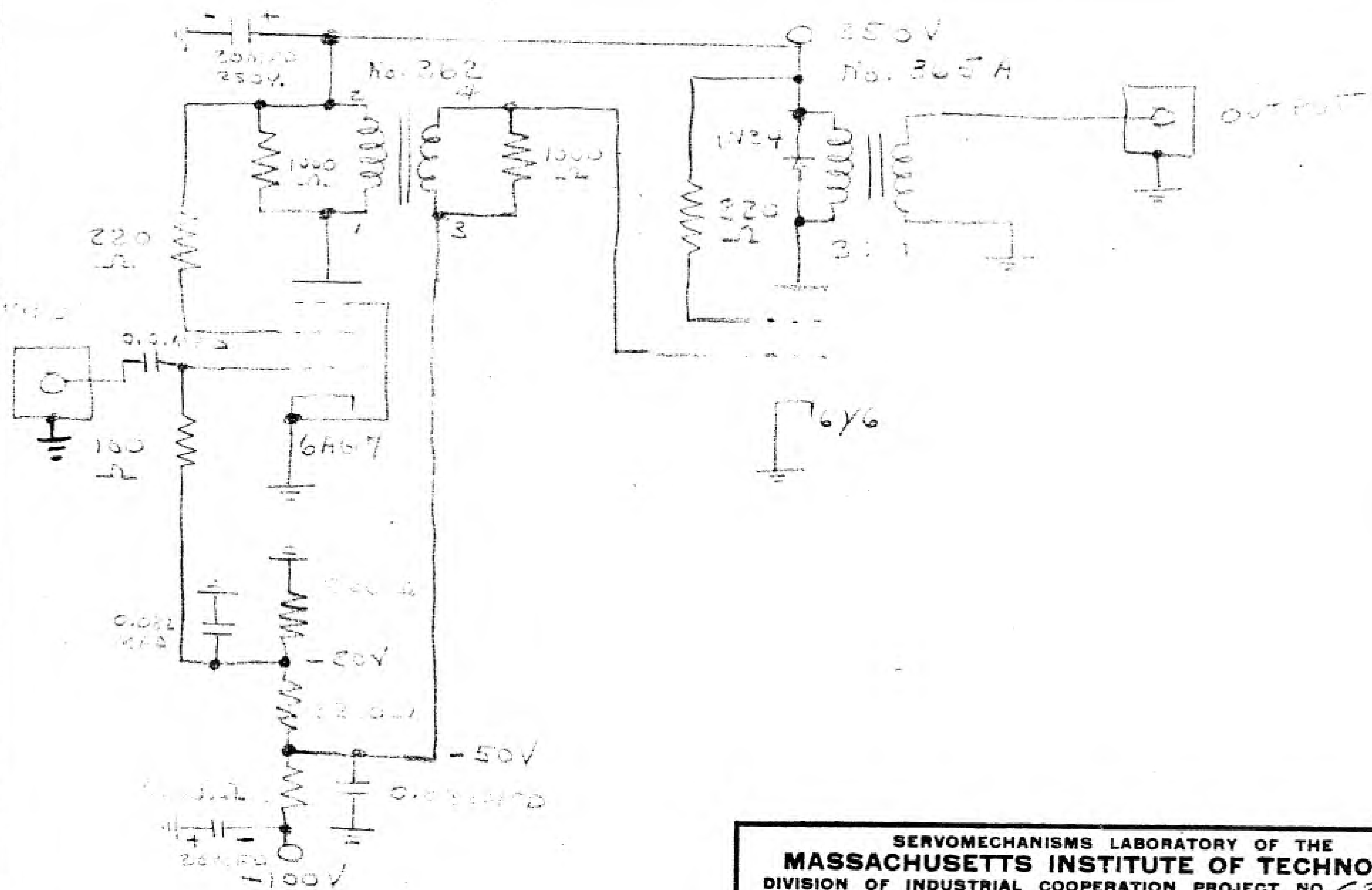
The flip-flops of the rack will again be triggered by a single driver. However, the first and last flip-flops and one in the middle of the line will also receive triggers on one of their control grids. This will test how much undesirable coupling exists between the flip-flop cathodes in this method of triggering. If all goes well this run can be short, less than 200 hours to prove the point in question.

Signed John J. O'Brien
John J. O'Brien

Drawings: SA-39372
SA-39443
SA-39444
SA-39445

References:
II JJOB 138-139
III JJOB 130-131, 133
IV JJOB 12-13, 41-48, 54, 56, 58, 61-66

SA-39372



SERVOMECHANISMS LABORATORY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DIVISION OF INDUSTRIAL COOPERATION PROJECT NO. 6345

RESTORER PULSE DRIVER FOR FLIP-FLOP LIFE TEST RACK

SCALE:	DR. J.J. OB 10-7-47		SA-39372
ENG J. J OB 10-7-47	CK.	APP.	

"ALBANENE" NO. 100L K&E CO., N.Y.X

SA-39443 USED IN 6345 MEMO M-13

TUBE NO.	PLATE CURRENT UNDER (A) TIME = 0	PLATE CURRENT UNDER (A) TIME = 500 HR	PLATE CURRENT UNDER (A) TIME 665 HR	CONTROL GRID VOLTS UNDER (B) TIME = 0	CONTROL GRID VOLTS UNDER (B) TIME = 500 HR	CONTROL GRID VOLTS UNDER (B) TIME 665 HR
	MA	MA	MA	-VOLT	-VOLT	-VOLT
1AV1	27.0	26.5	26.5	5.5	6.1	6.1
1AV2	27.0	27.5	26.0	4.4	4.2	4.2
1BV1	27.0	29.5	29.0	4.0	4.0	4.0
1BV2	27.5	25.0	20.0	4.5	4.7	4.6
2AV1	27.0	32.0	30.5	5.0	4.8	4.9
2AV2	27.5	27.5	25.0	4.6	4.3	4.3
2BV1	30.0	22.5	—	4.4	4.5	—
① 2AT		30.0	32.0	.	5.1	5.2
2BV2	30.0	28.0	27.5	4.2	4.2	4.2
3AV1	32.0	27.0	25.0	4.2	4.1	4.2
3AV2	32.0	28.0	25.0	4.8	4.7	4.6
3BV1	31.0	35.0	32.0	4.9	4.5	4.9
② 1AT		26.0	25.		4.2	4.2
3BV2	31.0	26.0	—	5.2	6.	—
4AV1	35.0	35.0	33.0	4.7	4.7	4.7
4AV2	35.0	33.0	32.0	4.5	4.4	4.4
4BV1	32.5	32.5	31.0	4.4	4.1	4.0
4BV2	32.5	31.0	30.0	3.0	4.4	4.4
5AV1	30.0	27.5	27.0	4.4	4.4	4.4
5AV2	30.0	29.5	27.5	4.4	4.3	4.3
5BV1	28.0	27.5	26.0	4.7	4.6	4.6
5BV2	28.0	31.0	27.5	5.2	5.1	5.3

TABLE (FORM M-138)

TUBE CH[illegible]RIST[illegible]

FLIP-FLOP LIFE TEST RACK

NOTE

	(A)	(B)
PLATE VOLTS	50	90
SCREEN "	90	90
C. GRID "	0	?
PLATE CURRENT MA.	?	1.5

① TUBE 2AT REPLACES 2BV1 FOR FIRST 165 HR.
② " 1AT " 3BV2 " " "

REF. E-64

SA-39244

USED IN 6345 MEMO M-12?

VOLTAGE CONTROL GRID TO GROUND								
FLIP FLOP	TIME = 0 HR.	=500 HR.	=637 HR.	=802 HR.	TIME = 0 HR.	=500 HR.	=637 HR.	=802 HR.
No.	V_1 VOLT	V_1 VOLT	V_1 VOLT	V_1 VOLT	V_2 VOLT	V_2 VOLT	V_2 VOLT	V_2 VOLT
1A	31.9	32.	31.5	31.8	32.	32.	31.5	31.8
1B	32.	32.	31.5	31.9	32.1	32.4	32.	32.2
2A	32.	32.2	31.5	32.	33.	33.1	32.5	32.8
2B	32.3	32.4	32.	32.2	31.9	32.	31.5	31.8
3A	32.	31.9	31.	31.3	29.9	30.	29.5	29.8
3B	31.2	31.1	30.5	31.	32.5	32.1	32.	32.3
4A	31.9	32.	31.5	31.7	32.	32	32.	31.9
4B	31.1	31.	31.	31.	31.1	31.	31.	30.9
5A	32.	32.	32.	31.7	31.	31.	31.	30.7
5B	32.4	32.5	32.5	32.5	32.2	32.2	32.5	32.2

TABLE (FORM M-138)

CIRCUIT VOLTAGES FLIP-FLOP LIFE TEST RACK

NOTE

1. ALL TUBES OUT.
2. REF. E-64

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SERVOMECHANISMS LABORATORY

D.I.C. NO. 6345 | DR. JJO'B 11/9/48 | CK. | APP. | SA-39244

USED IN 6345 MEMO M-138

SB-39445

TABLE (FOR M-138)

CIRCUIT VOLTAGES FLIP-FLOP LIFE TEST RACK

FLIP FLOP No.	CIRCUIT POINT	V₁ CONDUCTING TIME = 500 HRS V₁ VOLTS	TIME = 665 HRS V₁ VOLTS	TIME = 500 HRS V₂ VOLTS	TIME = 665 HRS V₂ VOLTS	V₂ CONDUCTING TIME = 500 HRS V₁ VOLTS	TIME = 665 HRS V₁ VOLTS	TIME = 500 HRS V₂ VOLTS	TIME = 665 HRS V₂ VOLTS
1A	PLATE TO GND	92.5	92.	124	125.	124	125.	83	83.
	C.GRID " "	34.	34.5	27.8	27.5	24	26.	34.5	34.5
	CATHODE " "	33.9	34.					34	34
	SCREEN " "	93.8	93.5					121.	124.5
1B		82.9	82.	122	124.8	124	125	85	87
		35.	35.5	24.9	25	25.2	26.5	35.1	35.2
		34.	35.					34.	33.
		121.	122.5					120.	122.5
2A		57	56.8	124	123	123	125	83.9	83.5
		35.1	35.2	26.8	27	25.	25.5	35.9	36.
		34.7	34.5					34.9	34.5
		107.	108.					112.	115.
2B (1)		85	83.	122	125	124	125	80.5	81
		35.6	36.5	25.1	24.5	24.3	24.7	35	35.2
		34.9	36					34.5	34.8
		111.	118					121.	124
3A		82	82	123	125	122	124	81.9	82.5
		34	34.5	22.9	23	24	24.5	33.	33.2
		33.4	33.7					32.5	32.5
		112	115					112.	115

3A		82 34 33.4 112.	82 34.5 33.7 115.	123 22.9	123 23	122 24	124 24.5	81.9 33. 32.5 112.	82.5 33.2 32.5 115
3B 2		85.1 35. 35. 110.	86 35.5 35.3 111.	122 25.7	125 26.5	122.5 24.3	125 24.5	84.8 36. 35. 112.	83.5 36.2 35. 121.
4A		78.8 35.8 36. 121.	78.5 36.2 36.2 123.	122 23.3	125 23.8	122.5 23.1	124.5 23.7	79.1 36. 36. 120.	79.5 36.5 36.2 123.
4B		81.2 34.6 34.9 116.	82.5 36.3 35.3 120.	123 23.5	125 24	122. 23.	125 22.5	80.2 34.9 34.8 121.	81 35.3 35.3 119.
5A		81.6 35. 35. 123	81.5 35.5 35. 124.	124 23.2	125 23.6	123 24.4	124 24.7	82.1 34.8 34.6 123.	82.3 34.5 34.5 124.
5B		84.1 34.5 33.9 114.	84.5 35. 34. 117.	124. 25.1	125. 25.8	124 26.2	124 26	87.1 35. 34.1 103.	87.8 35.2 34.5 107.

NOTE

CIRCUITS NOT TRIGGERED.

TIME FOR RESISTORS = 802 HRS.

" " TUBES = 665 "

1 FOR LAST 165 HRS. TUBE 2BV1 WAS REPLACED BY 2AT

2 TUBE 3BV2 REPLACED BY 1AT

2

6345 WJB 11/9/47

SB-39445

MEMORANDUM NO. M-77

SERVOMECHANISMS LABORATORY
Massachusetts Institute of Technology
Cambridge, Massachusetts

TO: 6345 Engineers — 6345

FROM: Norman H. Taylor — Page 1 of 4 pages

SUBJECT: Use of D. C. Restorer Circuits as a Means of Eliminating D. C. Coupling in Digital Computer Circuits. — Drawing: SA-39216

DATE: May 28, 1947

Purpose - One of the most common problems in digital computer circuits is that of storing information in a flip-flop and using the position of this flip-flop to open or close a channel of gate tubes or select one position of a matrix switch. (In WHIRLWIND I). This channel selection may last for as short a time as .25 μsec. up to several hours, so it has seemed necessary to employ D.C. coupling in the system. The resulting design which necessitates buffer amplifiers and cathode followers on flip-flop circuits calls for power supplies at as many as 10 or 12 D.C. levels. The problem of absolute voltage level becomes very serious and voltage regulation at relatively high current appears necessary. This is, of course, expensive in terms of quantities of tubes used in power supplies. It also associates the reliability factor directly with the power supply regulation. Filaments of various stages running at different D.C. levels call for a large number of transformers.

A system of A.C. coupling would avoid most of these difficulties and have some other advantages, such as:

1. Allowing use of somewhat smaller signal levels, as overdesign to overcome D.C. level drifting would not be necessary.

2. Smaller signal level would permit higher speed operation.

Method of Achieving A.C. Coupling - Two basic methods of using A.C. coupling have been suggested to date:

1. At periodic intervals in the program, a complement and recomplement pulse may be sent to each flip-flop.

This process would take up only a short portion of the time in the period between complementary pulses.

2. The flip-flop may be used as a means of holding open one of two gate tubes representing a 1 or a 0, and sending preformed gates through the gate which is open.

The first method necessitates putting complementing and re-complementing pulses in the program. For "push button" operation, a special circuit to complement and recomplement before each step of "push button" operation is needed. This system can be considered as one in which the flip-flop acts as a gate generator as well as a digit storage unit, the gate being on 95% of the time and off 5% of the time for a zero and off 95% of the time and on 5% of the time for a one.

The second system needs one stage of D.C. coupling between "flip-flop" and gate tube but does not call for complementing and the associated programming. Some complication does arise, however, in the decoupling which is needed between the gate signal and the flip-flop. The preformed voltage in the plate of the flip-flop would be enough to change the position of the flip-flop circuit, and hence decoupling is necessary.

In both of the above methods, coupling to succeeding gates, buffers, switches, etc., may be accomplished using a simple D.C. restorer circuit as shown on Drawing SA-39216.

In sketch A, the crystal diode is arranged to clamp on the positive signal and produce a negative bias. If this amplitude is relatively large with respect to tube cut off as shown, decay between pulses will occur below cut off and no change in the operation of the gate or buffer will be observed.

In sketch B, the diode is arranged to clamp on a bias voltage which will hold the gate or buffer normally off. The long gates will produce positive bias and turn the tube on. Here, however, condenser decay between pulses produces a direct change in operating point of the "on" tube and could cause considerable change on signal level.

Choice of coupling condenser "C" will depend on the circuit used. If the coupling is from the plate of a "flip-flop", the coupling condenser may need to be as small as 100 MMF in order to allow the flip-flop to start and switch rapidly. Preliminary experiments indicate that this small condenser is still useable. If a 30-volt swing is available at the start of period, after 20 microseconds 20 volts is still available on the grid of a

succeeding gate tube. This still gives a large factor of safety below cut off.

In circuits other than flip-flops, such as, buffers, cathode followers, etc., it is not necessary to use such low values of capacitance. In fact, if a large enough condenser is employed, such as, .01 MFD, the objection shown in sketch B, Drawing SA-39216 is no longer valid and it becomes reasonable to use either scheme as a means of coupling. This method does have a limitation however in that the initial bias on the coupling condenser may not be attained in a single complement and re-complementing pulse. This method would require the gate generator, whether it be the flip-flop or another source, to run for a millisecond or so before the condensers become charged. Once charged, however, no limitation is placed on switching speed or repetition rate as long as gates are generated at intervals short with respect to the time constant of the coupling circuit. See sketch C, Drawing SA-39216.

Comments - When applying this type of coupling to preliminary designs of WHIRLWIND I, several problems arise which demand separate treatment. The list below indicates the thinking to date on these problems and how they may be overcome.

Accumulator

The four-position matrix switch in the Accumulator when used with the Restorer schematic described on sketch A, Drawing SA-39216, calls for a pulse on all three unselected output lines.

To achieve this, it is necessary to cause the complementing of the two flip-flops to occur one after the other instead of simultaneously and thus pass through the four positions of the switch. A solution to this problem is possible by installing a delay line between the two flip-flops connected to the four-position switch and complementing one before the other. This adds only one piece of cable and appears to be a simple solution.

32-Position Switch

It is necessary here as well as in the Accumulator to keep pulses coming on all thirty-one unselected lines. Apparently, such pulses do exist due to the change-over period of the flip-flops. During this period, all thirty-two lines go to B^+ as both buffers on the flip-flop tubes are cut off during the switching period. There is a good possibility that this condition may be useable as a means of obtaining pulsed output as a source of D.C. restoring voltage on each of the thirty-one unselected lines.

Neon Bulb Indication

There is a possibility that neon bulbs will not deionize between the 20 μsecond complementing periods and continually show a glow in the off position. An R.C. filter in the grid circuit of the neon buffer with a carefully selected time constant should eliminate this difficulty.

Toggle Switch Storage

At present, the selected line presents a positive 15-volt D.C. signal to a gate tube and causes the selected line to be opened. A.C. coupling may be applied here if the circuit of sketch C, Drawing SA-39219 is applied. However, high capacity of switches may cause complications. This problem is being given further consideration.

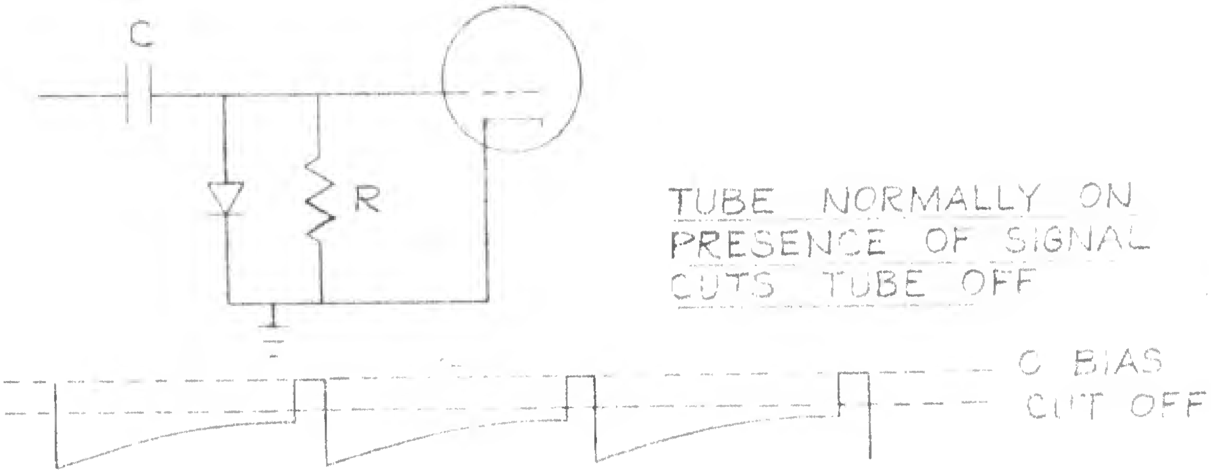
6AS6 Gate Tube

It has been pointed out that the 6AS6 gate tube presents a problem if grid No. 1 is used as the high duty factor control. Screen dissipation with grid No. 3 cut off runs above rating when 100 volts is applied. Methods of overcoming this problem are being considered, such as pulsing suppressor and screen together.

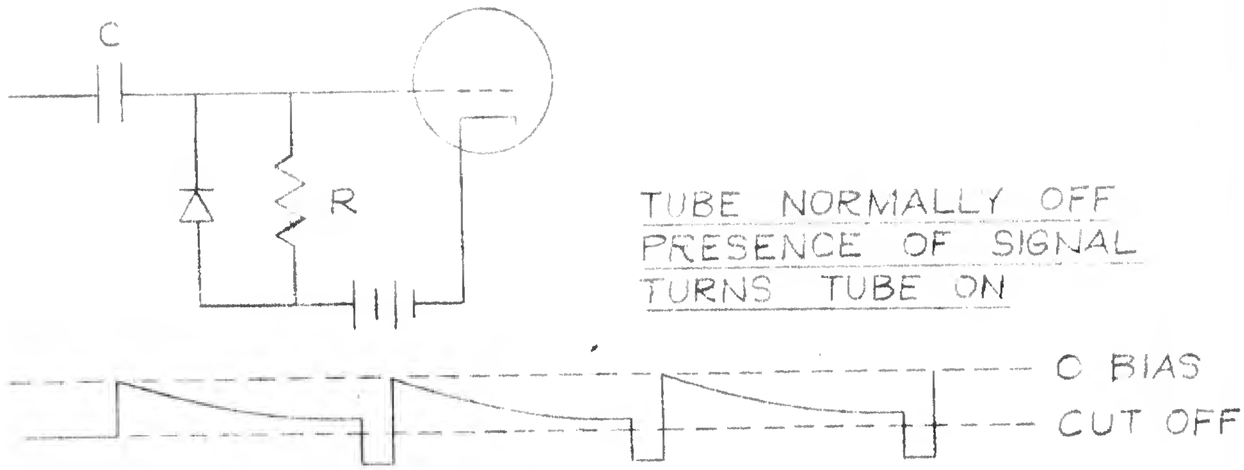
Norman H. Taylor
Norman Taylor

NT:has

D.C. RESTORER METHODS

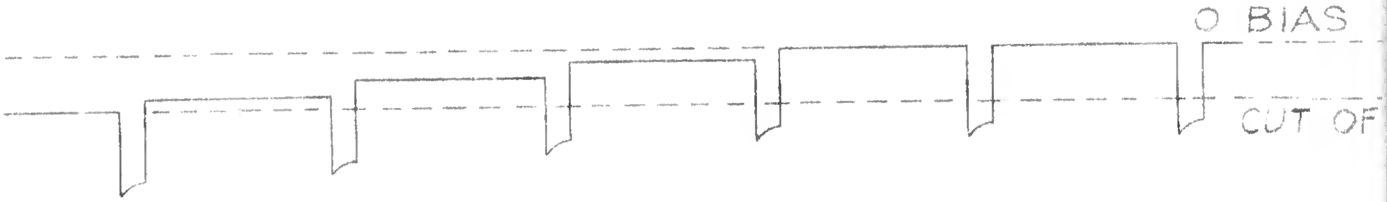


SKETCH A



SKETCH B

CONDITION WHEN COUPLING CONDENSER C IS LARGE
A TIME CONSTANT RC LONG
OTHER CONDITIONS SAME AS SKETCH B



SKETCH C

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D.I.C. No. 6345	BY WJC 5/2/47	CK
ENG NHT	APP	SA-39216

SA-39216

ENGINEERING NOTES NO. 39

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

TO:	6345 Engineers	6345
FROM:	A. B. Horton, Jr.	Page 1 of 2 pages
SUBJECT:	Testing of A.C. Coupling between Flip-flop and Buffer and between Matrix Switch and Gate.	Drawings: SA-39269, SA-39267-1, SA-39268-1
REFERENCE:	Memorandum No. M-77	
DATE:	July 1, 1947	

Tests were made on an experimental unit of the A-register, B-register, and Accumulator, for the purpose of observing the behavior of D.C. Restorers, which have been proposed as a means of eliminating D.C. coupling in digital computer circuits. Specifically, characteristics of the A.C. coupling between flip-flop and buffer amplifier (both using type 6AG7 tubes), and between diode matrix switch and 6AS6 gate tube were taken. Results are shown graphically in Drawings SA-39269, SA-39267-1, and SA-39268-1.

Test Procedure and Results

In order to simplify the testing of the unit, it was desired to work with only one of the two flip-flop registers, thereby selecting alternately only two of the four channels controlled by the four-position diode matrix switch. This simplification was attained by removing one tube from the flip-flop not to be operated, thus assuring that it would remain in one conducting state and not be flipped over by random noise or transients.

Complementing pulses of 0.5 μsec. duration were produced by the operating flip-flop from set and reset pulses supplied in the following manner. A multivibrator designed to free-run at a 100 kilocycle per second repetition rate, and driving an R-L-C peaker and cathode-follower produced 0.05 μsec. trigger pulses. These 100 KC pulses were fed simultaneously into the flip-flop trigger tube and an open-circuted 0.25 μsec. delay line, thereby operating the flip-flop so as to obtain a 0.5 μsec. complementing pulse.

A resistor value of 100K was used to shunt the 1N34 crystal diode in the restorer circuit so as to make the tests under the worst possible conditions of condenser discharge path. In the final design, a 1N38 crystal will be used alone, and a crystal with back resistance of less than 100K at -10 volts will be considered unsatisfactory.

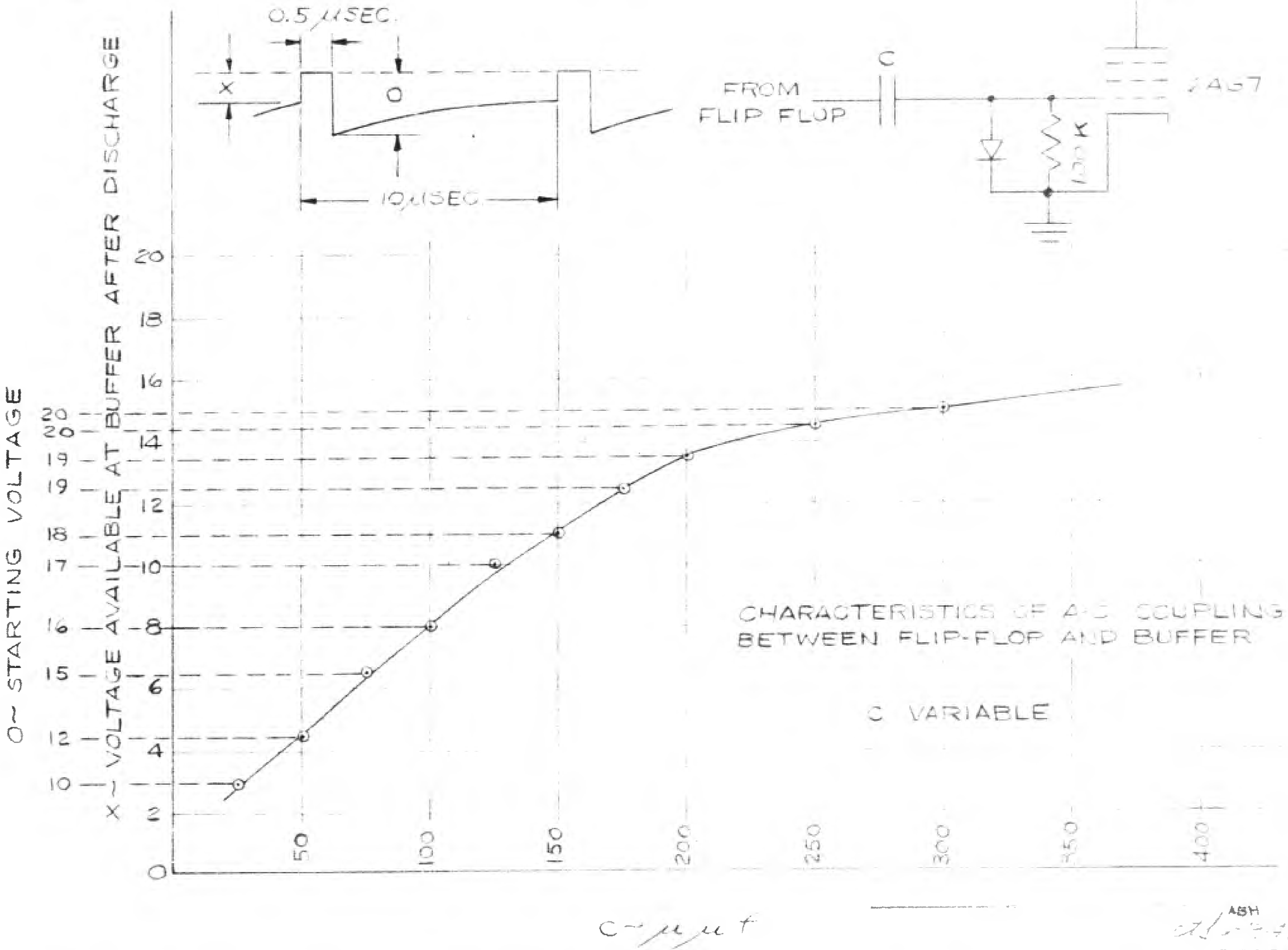
The value of the capacitor C was varied and measurements made of the voltage remaining at the grid of buffer tube and gate tube respectively after the 10 μsec. interval. Starting voltage values are on the resulting graphs. It was found that if the value of C between flip-flop and buffer was greater than 200 μμf, the flip-flop operation was faulty because of excessive capacitive loading. In addition, voltage remaining on the plate of the gate tube with a 1000 ohm plate load was measured and plotted as a function of C.

Finally, both flip-flops were operated simultaneously in a manner similar to that described above. This test produced essentially the same results, and it is thought that no new problems will be introduced by simultaneous operation.

A.B. Horton, Jr.
A. B. Horton, Jr.

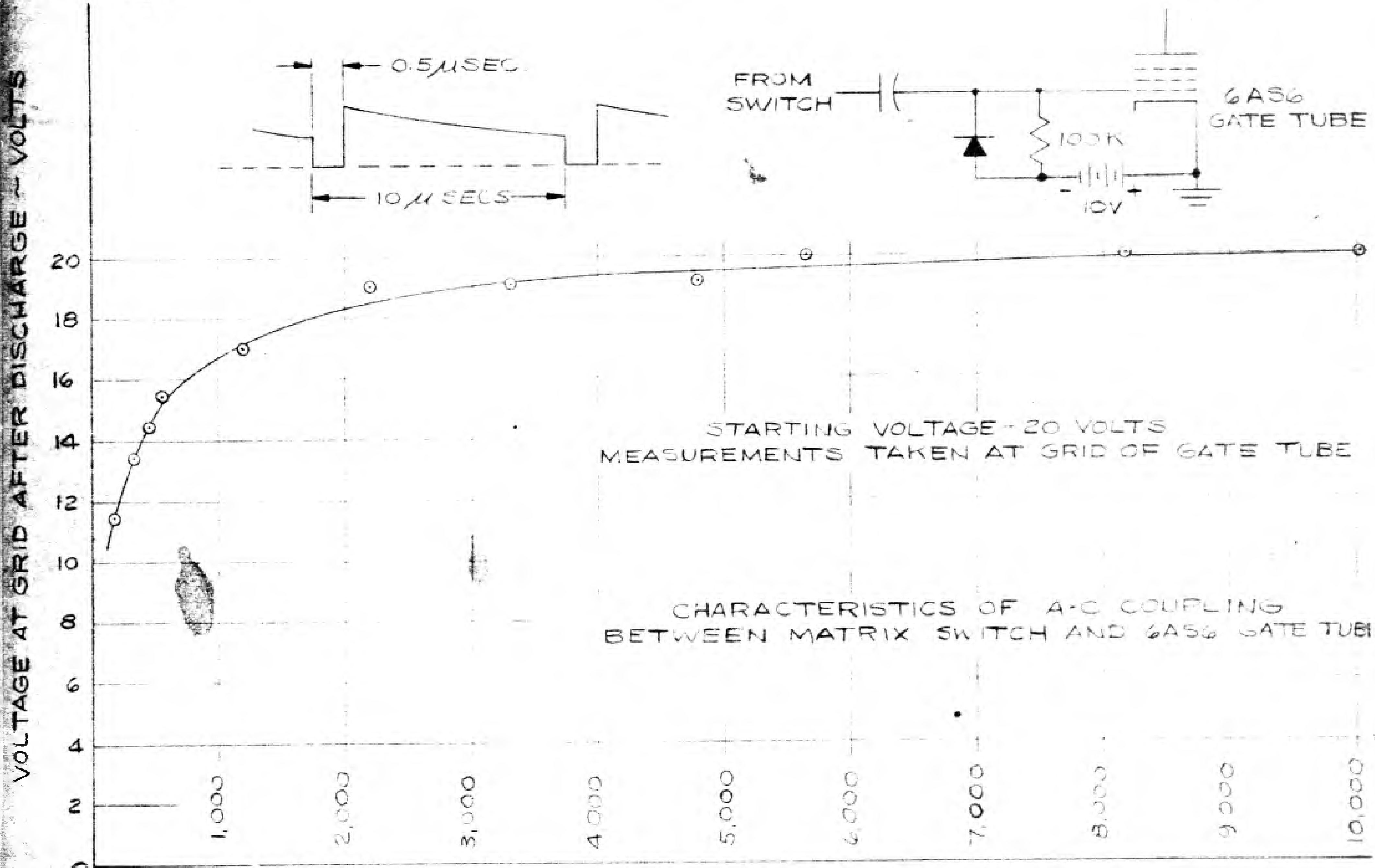
ABH:has

SA-3926



ABH
SA 39269

SA-39267-1



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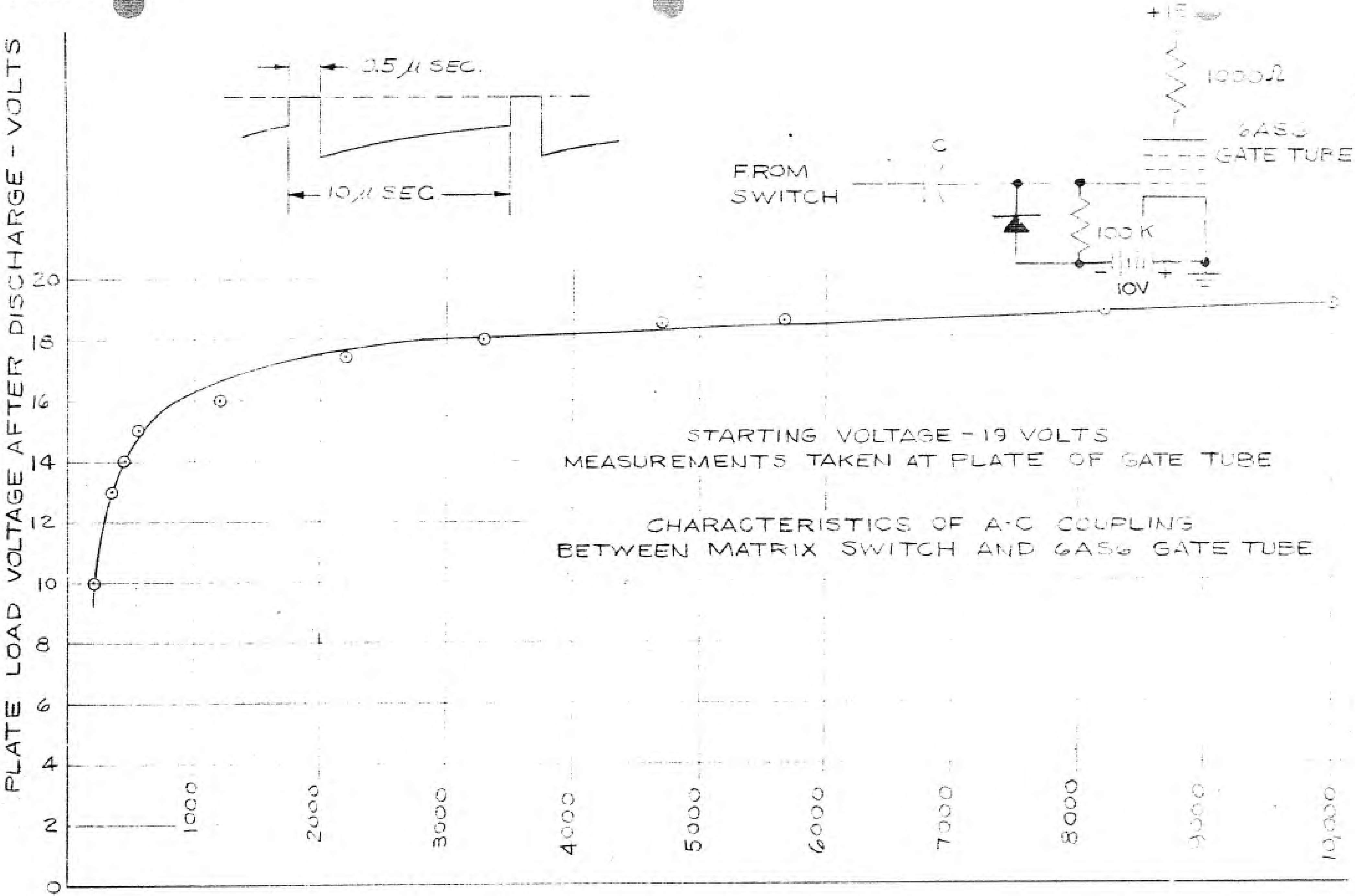
SA - 39267-1

SA-39268-1



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D.I.C. NO. 6345	ASH 6-18-47 SA-39268-1

MEMORANDUM [illegible]

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

To: 6345 Engineers and Technicians
Sylvania Whirlwind Group (3 copies)

[illegible]

Page 1 of 1

From: N. [illegible]

Subject: Terminology in AC Coupling

Reference: M-77, E-30

The above references [illegible] detail method of AC coupling which will be used in WWI. [illegible] of leakage on condensers which determine bias is prevented from becoming excessive by a bias restorer method consisting of pairs of flip-flop switching operations, the pairs of operations occurring at [illegible] microsecond intervals, the two operations of a pair being separated by [illegible] microsecond.

The mathematical process of complementing a number is performed by reversing the state of all the flip-flops in a register. This terminology has been extended on this project to express the need as "complementing a flip-flop" or "complementing" and [illegible] to describe the above method of bias restoration. The expression "complementing a flip-flop" is probably unintelligible to engineers not on this project. Ambiguity arises as to whether complement pulses mean single pulses or pairs of pulses and confusion may arise as to whether one is referring to a mathematical or electrical operation.

In order to avoid confusion in referring to the pulses and operations introduced for bias restoration the following terminology is recommended.

Restorer pulses - Pairs of pulses introduced periodically for bias restoration.

Restorer pulse - One pulse of the above pair.

Restorer pulse generator - [illegible] and associated circuits to provide a sequence of restorer pulses.

Complement pulse - A pulse introduced into a [illegible] register for the purpose of obtaining the complement of the number stored therein.

N. [illegible]

N. [illegible]

[illegible]

ENGINEERING NOTES NO. E-47

Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

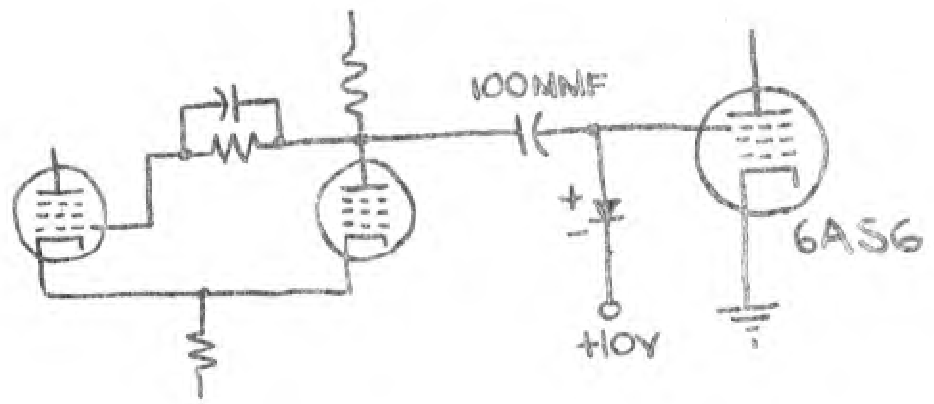
TO: 6345 Engineers

FROM: David R. Brown

SUBJECT: A-C Coupling and 6AS6 Operation

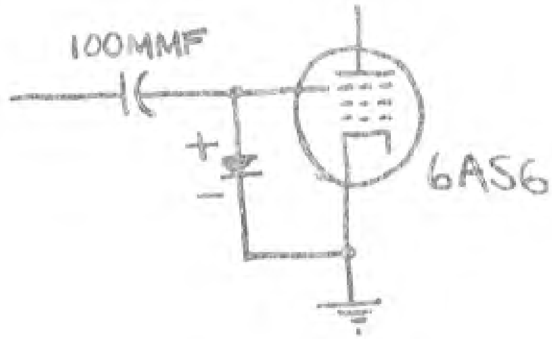
DATE: July 16, 1947

A meeting was held this morning to discuss the problem of coupling from a flip-flop to a gate tube. The present method has many disadvantages. It is shown here.

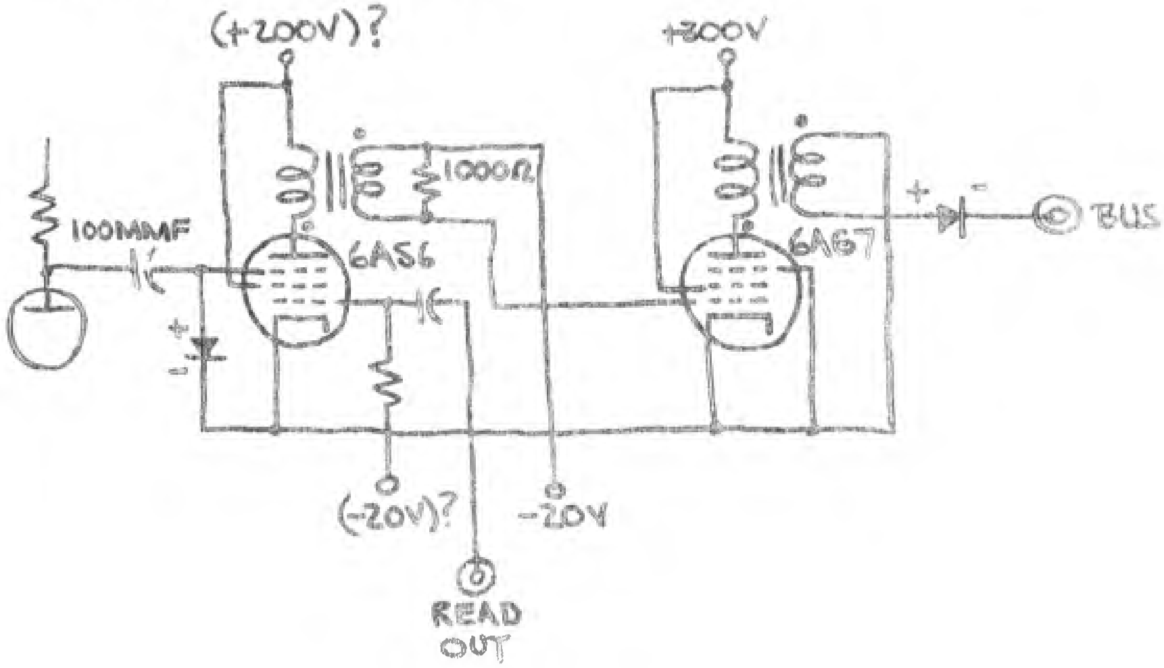


When the control grid of the 6AS6 is hit, the suppressor draws current; it looks like about 5,000 ohms and discharges the 100 MMF coupling capacitor. This not only reduces the suppressor voltage, but puts a negative pulse on the "on" tube in the flip-flop, possibly causing it to switch.

One way out it to drive the suppressor of the 6AS6 only to cathode potential. That is,



In order to do this, the plate and screen voltage of the 6AS6 must be increased to get sufficient plate current. There will be a consequent increase in the control-grid and suppressor cutoff voltages. With plate-supply and screen voltages of 200 volts, the plate current will probably be about 25 ma at zero control-grid and suppressor voltage. The control-grid cutoff voltage will be about -10 volts. That means that the fixed control-grid bias should be about -20 volts. A load resistance of about 1,000 ohms should provide a satisfactory plate swing. The usual read-out circuit looks something like this:



Since the read-in gate circuits will all be the same, it may be possible to eliminate the coupling circuit on the read-in gates by connecting the line-driver transformer to -20 volts instead of ground.

David R. Brown
David R. Brown

DRB:has